Monts Doudou, Gabon
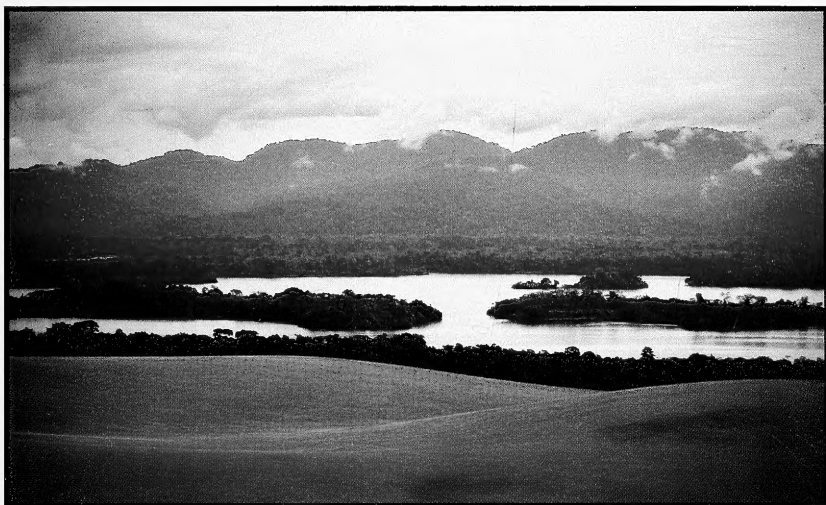
A Floral and Faunal Inventory
With Reference to Elevational Variation

Edited by

Brian Fisher

MONTS DOUDOU, GABON
A FLORAL AND FAUNAL INVENTORY
WITH REFERENCE TO ELEVATIONAL DISTRIBUTION

FRONTISPIECE. *Hemisus perreti*, a taxon new to Gabon, was collected in the Monts Doudou Reserve.

MONTS DOUDOU, GABON
A FLORAL AND FAUNAL INVENTORY
WITH REFERENCE TO ELEVATIONAL DISTRIBUTION

Edited by

Brian L. Fisher

CALIFORNIA ACADEMY OF SCIENCES
GOLDEN GATE PARK

TABLE OF CONTENTS

Preface

In this volume we present results of a brief floral and faunal survey, and a small mammal population study in Monts Doudou, located in the Reserve de Faune de la Moukalaba-Douboua and the Aire d'Exploitation Rationnelle de Faune des Monts Doudou in southwestern Gabon. The vertebrate survey team was in Monts Doudou between 24 February and 21 March 2000. The botanical crew conducted their work from 16 March–27 September 2000 and the small mammal team conducted their population study from April–October 2000. Monts Doudou is part of the Gamba complex of protected areas. The Gamba complex is one of the biological jewels of the Congo Basin. Its privileged position in terms of biodiversity is based on its diverse habitats and gradients. The region offers a rich variety of natural habitats including different types of forest (swamp, flooded, and terre firme), the savannas of the Nyanga plains, the immense papyrus marshes close to the mouth of the river Nyanga, and the Raphia marshes of the Rembo Ndogo. The Doudou Mountains were the least explored area of the Gamba complex and thus we were delighted to be among the first to visit this region.

Our survey of Monts Doudou was organized under the auspices of the World Wide Fund for Nature (WWF), Central Africa. Since the Monts Doudou survey, we have conducted a similar inventory in the Parc National Dzanga-Ndoki, in the extreme southwest of the Central African Republic. Each of these sites is a focal point of conservation efforts by WWF in collaboration with host country scientists and government agencies.

Collecting information about the living things on this planet is fundamental to reaching the goal of basic science and conservation. Even after 200 years of biological exploration, we have few answers to these simple questions: What kinds of living things exist? Where do they live? How are they related? Based on the fact that you can identify any bird in North America and Europe with a small field guide, it is easy to think that we know enough about life on this planet and that 19th century field collecting is no longer needed. It is a shock to most people to realize how little we know about the diversity of life on this planet. Systematists have identified 1.7 million species—a mere fraction of the creatures living on this planet.

We are pleased that WWF incorporates survey work to achieve its conservation goals in the Congo Basin. Critics of inventory programs have asked these questions: Why should we invest in collection and analysis of biodiversity information globally, when habitat and species are disappearing so fast? Should we rather support protection and preservation? Maybe we don't need to know very much about it to preserve it. How can collecting and knowing the species living on Earth help conserve them?

Conserving tropical biodiversity into perpetuity consists of three basic and overlapping steps—save it, know it, and use it. The direct "save it" step often requires knowledge of where biodiversity is located and requires limited inventories and mapping diversity. However, if only this first step is executed, the "conserved" tropical wildland has very little chance of long-term survival, no matter how scientifically well-founded, legally bound, or esthetically attractive. Once an area is "protected," the second and third steps, termed "biodiversity development" by Daniel Janzen, must be applied so as to generate perpetuity of conservation status. We are convinced that long-term conservation of tropical habitats

1

will only come about through their non-damaging use by local, national and international societies.

"Inventory," an action that demands some kind of a taxonomic infrastructure, is not a list but rather a process of making biodiversity information accessible for all users across society, whether the users are local village children on a guided tour of a park, bioprospectors or local populations looking for medicinal plants, national park managers, or any other sector of society that needs to access the environment. With respect to conservation, inventory has its purpose in setting up those conserved habitats for relatively non-damaging uses. Thus, we will be much more effective at protecting something (at much lower cost), when we understand it. Systematics and the required collections are therefore, the foundation for long-term conservation.

With long-term conservation and local management as our objectives, we conducted an elevational transect of the Doudou Mountains, focusing on several groups of vertebrates and invertebrates. We employed rapid assessment techniques to survey the fauna at three elevations along the western slope of the mountain, including forest at the lowest elevation, mid-elevation, and the summit zone. The aim of our study is to provide data to address the following issues and questions relevant to the conservation and management of this mountain: 1) patterns of elevational variation of the fauna; 2) how these patterns compare to similar studies elsewhere in central Africa; and 3) the biogeographic attributes of the montane fauna in relation to the Pleistocene refugia hypothesis.

The survey team moved in unison up the slopes of the reserve, except for the small mammal population study and the botanical study. The survey was conducted during the rainy season from February – March, because the greatest reproductive activity of many organisms occurs during this time and because many organisms are more conspicuous, more easily identified, and more abundant during the rainy season.

In most cases, standardized quantitative techniques were used to survey target taxa. Quantitative methods are essential in inventories. They permit an evaluation of the completeness of the survey effort, comparison with other sites, and allow the survey to be repeated for future monitoring programs. Though our efforts relied on quantitative techniques, the time spent in the field was relatively short, and thus could not include a complete inventory of all taxa. Our survey, however, provides a baseline of information, which future studies can build upon.

We dedicate this volume on Monts Doudou to Faustin Oyono, who died in an accident shortly after the expedition. Faustin Oyono was one of the most promising students in forestry, an essential member of the expedition, a natural leader, and an advocate for conservation.

Brian L Fisher
15 October 2003
San Francisco

Description of Monts Doudou, Gabon, and the 2000 Biological Inventory of the Reserve

Marc Thibault

*World Wildlife Fund, Central Africa Regional Program Office,
email: thibaultmjt@hotmail.com*

Brian L. Fisher

*Department of Entomology, California Academy of Sciences,
Golden Gate Park, San Francisco, California 94118*

and

Steven M. Goodman

*Field Museum of Natural History, Roosevelt Road at Lake Shore Drive,
Chicago, Illinois 60605,
and WWF, B.P. 738, Antananarivo (101), Madagascar*

This study highlights the urgent need to map biodiversity. Given the current levels of world habitat loss and continued high rates of deforestation, a biodiversity map is essential for effective conservation practices. In basic sciences, this map is needed to understand the complex historical factors that have shaped the origin and evolution of life. Now is the time to document and analyze biodiversity before the chance is forever lost.

This volume presents the results of a biological inventory conducted in Monts Doudou (Doudou Mountains) located in southwestern Gabon in the Gamba Complex of protected areas (Fig. 1). Seven scientists participated in the field inventory, which took place in 2000. This chapter briefly describes the Monts Doudou region, the organization of our 2000 field season in the region, geology, climate, and weather conditions during the expedition.

The Gamba Complex (1°50′–3°10′S; 9°15′–10°50′E) is the largest protected area in Gabon covering 11,320 km^2 bordering the Atlantic Ocean and extending up to 100 km inland. This region is one of the Congo Basin's most diverse in terms of habitats. Starting with the coast, they include beach and dunes, littoral forest, mangrove forest, coastal scrub forest, freshwater swamp, lowland seasonally flooded forest, upland non-flooded forest, open grassland and extensive lagoons and lakes adjacent to the ocean. Further inland—the location of the present study—are extensive tracts of upland forest dissected by lowland, seasonally flooded forest along rivers and streams. World Wide Fund for Nature (WWF) identified three global ecoregions in the Complex: Atlantic Equatorial Forest, Guineo-Congolian Coast Mangroves, and the Western Congolian Forest-Savanna Mosaic (Olson and Dinerstein 1998).

The Complex is currently divided into multiple zones with varying degrees of protection:
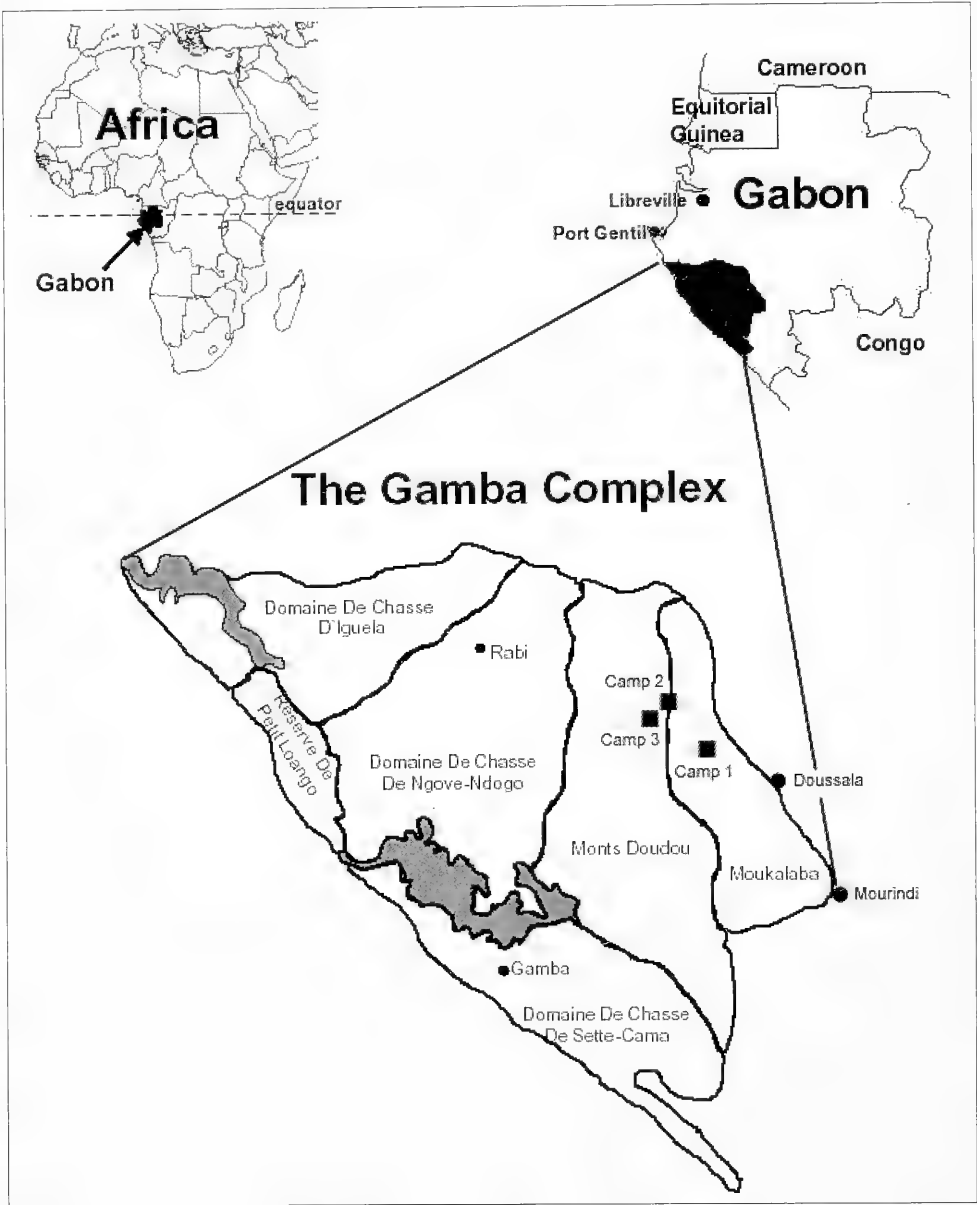
FIGURE 1. Localisation de l'Aire d'Exploitation Rationnelle de Faune des Monts Doudou.

- l'Aire d'Exploitation Rationnelle de Faune (AERF) de Moukalaba-Dougoua (decree number 1484/MEF/SF-5225 of 17 November 1962) comprising the Réserve de Faune of Moukalaba-Dougoua and the Domaine de Chasse of Moukalaba;

- l'Aire d'Exploitation Rationnelle de Faune des Monts Doudou (decree number 000105/PR/MEFR of 28 January 1998). The relief is uneven and ranges to 700 m in elevation.

- l'Aire d'Exploitation Rationnelle de Faune de Setté Cama (decree number 1487/SF-4225 of 17 November 1962 and decree number1571/SF-CHPP of 29 December 1966) comprising the Réserve de Faune of Petit Loango, the Réserve de Faune of Plaine Ouanga, Domaine de Chasse of Setté Cama, Domaine de Chasse of Ngové-Ndogo and Domaine de Chasse of Iguéla.

The study was concentrated in the AERF de Moukalaba-Dougoua and AERF de Monts Doudou.

Transect Sites

This study included three elevations along the eastern slope of Monts Doudou: forest at the lowest elevation (110 m), mid-elevation (375–425 m), and the summit zone (585–660 m). The following three sites were inventoried:

110 m (Camp 1) - Province de Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 40.2 km 324° NW Mourindi, 2°17.00'S, 10°29.83'E, 110 m, lowland rain forest, 24 February–4 March 2000.

350–425 m (Camp 2) - Province de Ogooué-Maritime, Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 52.1 km 321° NW Mourindi, 2°13.35'S, 10°24.35'E, 350–425 m, mid-elevation rain forest, 5 March–12 March 2000.

585–660 m (Camp 3) - Province de Ogooué-Maritime, Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 25.2 km 304° NW Doussala, 52.6 km 321° NW Mourindi, 2°13.63'S, 10°23.67'E, 585–660 m, mid-elevation rain forest, 14 March–21 March 2000.

Itinerary of the 2000 Expedition

Reconnaissance (6–16 February 2000) was conducted by Fisher to determine the route for the elevational transect. Monts Doudou was accessed through the village of Doussala, which is accessible by vehicles via the Tchibanga-Moabi road and then north by road to the villages of Mourindi and then Doussala. Since maps indicating the major peaks of the reserve were not available, Fisher traversed 75 km through the reserve, exploring the highest reaches. Camp 3 at 660 m was the highest peak encountered within the protected area. Over the past 40 years, selective logging has occurred at several locations of the Gamba Complex, though much of the area explored during the reconnaissance was undisturbed. The network of abandoned forestry roads, however, provided access to Camps 1 and 2. Local help was hired from Doussala to prepare the road and bridges to Camps 1 and 2.

The vertebrate survey team was in Monts Doudou between 24 February and 21 March 2000. The botanical crew conducted its work from 16 March–27 September 2000 and the small mammal team conducted its population study adjacent to Camp 1 from April–October 2000. See Appendix 1 for a complete list of research participants.

GEOLOGY

The geological formation in the Gamba Complex dates to the Quaternary. The region consists of the two principal soil types found in Gabon: coastal sediment and terrestrial crystalline soils. The Monts Doudou Reserve is situated at the limit of the sedimentary basin with a large part of the surface in the Mayombe mountain chain. The Mayombe chain extends 450 km long and 30 km wide, is 2.7 million years old and consists of three series from the base to the summit:

- Doussa series: migmatite, metasomatic granite, septa of metamorphic rocks (thin granular of gneiss);

5

- Kouboula mountain chain series: metamorphic series of quartzite and mica-schist with granitization;

- Douigni series: metamorphic series of mica-schist, amphibole-schist, quartzite (200 m thickness) with some intercalation of basic metavolcanit (talc-schist, epidotes) in the lower part and locally of acidic metavolcanit in the upper part: tufa, porphyroïds (metarhyolit) (MENIPN 1983).

The most recent section dates from 2.7 to 1.7 million years and includes conglomerates, arkose, quartzite and chloro-schist (MENIPN 1983). Near the village of Digoudou, on the North of Nyanga; the particular geology of the site is reflected by spectacular extrusions of metamorphic rocks derived from limestone or from dolomites often veined by a variety of colors.

Soil

The pedology of the Gamba Complex is characterized by ferralitic and hydromorphic soil. From the coast to the hinterland, ferralitic soils predominate in the coastal sedimentary basin, characterized by their lower topographic position and under the influence of the water table. Their texture is sandy clay (20–30% argil) to clayey sand (30–45% argil). In the inundated forest, the soil is composed of sulfur material near the surface. The swampy plants accumulate pyretic materials on the roots and when the soil desiccates, oxidation produces sulfuric acid resulting in a pH of 3.0 to 3.5. In areas where the soil is regularly subjected to floods, a lateritic layer could develop at a depth equal to the water table. (Environmental Resources Management 1999).

The forest soils are covered by a thin layer of organic material that is reduced as the degree of humidity increases. In the savannas, the organic layer is less developed and could even be removed by erosion. The mineral surface possesses a thin epipedon resulting from the organic layer of sandy particles. The soil horizons are gray pale or ochre in color (Environmental Resources Management 1999).

In Monts Doudou, the soils have a higher rate of argil (60%) and although they are not deep, they represent the richest soils of the Gamba Complex. Sensitive to erosion, they are protected by the vegetation cover. On each side of the Moukalaba River, the savanna overlying limestone-schist is situated in the peneplain at 100 m altitude, subject to karstic evolution and rising of the water table during the rainy season. They are not particularly suitable for agriculture (MENIPN 1983).

As throughout Gabon, the mineral content of the soils found in Monts Doudou is poor and their structure fragile. The soils are susceptible to erosion and rapidly lose their nutrient elements after slash and burn agriculture.

Hydrology

The occurrence of surface water in the natural habitats makes an important contribution to species richness and ecosystem diversity in the Gamba Complex. The hydrology network of the Gamba Complex is divided into three principal watersheds: the Nyanga River, the Ndogo lagoon, and the Ngové lagoon. Monts Doudou is drained by the Ndogo watershed and by the Nyanga, which is the largest river in Gabon. The Nyanga drains a watershed of 22,500 km^2, of which 80% is situated in Gabon. The river enters Monts Doudou at its confluence with the Moukalaba 110 km from the Atlantic Ocean. Thereafter, a series of rapids and waterfalls marks its route for a distance of 40 km — as far as Igotchi. After Igotchi, the Nyanga snakes across the alluvial littoral formation in the mangrove zone for a distance of 55 km before reaching the ocean (MENIPN 1983). In Monts Doudou, the sec-

ondary water routes of the Nyanga watershed are the Mingandou, Yara, Dugungu, Bidugu and Mbani rivers. The Bidugu River forms the boundary between the lands of the Batsiengui and Moubaoulaou villages, while the Mbani River forms the boundary between the Digoudou and Moruindi villages. The principal lakes, which support fishing, are Tsougou Natsougou, Kambela, Mingangandou, Mibundzi, Mirobou and Munumboumba.

The Ndogo lagoon has a surface area of 733 km^2 and drains a watershed of 1,587 km^2. Rembo Ndogo (Ndogo River), the principal tributary of the Ndogo lagoon, is the second largest watercourse in Monts Doudou and drains a surface area of 412 km^2. The other watercourses of Monts Doudou that exit into the Ndogo lagoon watershed include the Doudou, Moukiama, Doufoucou, and Bibanga rivers.

<center>SOCIO-ECONOMIC ENVIRONMENT</center>

Inside the Gamba complex, there are 0.8 inhabitants per km^2, distributed in 35 villages and the city of Gamba (MPEAT 1993; Blaney et al. 1997; Blaney et al. 1998; Blaney et al. 1999; Mboumba Mavoungou et al. 1999). If the city of Gamba is excluded, the population density is only 0.2 inhabitants/km^2. The rural communities are migrant populations established in successive waves between the 18th and the end of the 19th century (MENIPN 1983). The primsary ethnic groups found in the Complex originated in the Congo.

The Vilis, whose migration path is somewhat older, clashed with the Nkomis at the end of the 17th century and at the beginning of the 18th century. One part of the ethnic group established itself along the Atlantic coast. The Lumbus, from the Pointe-Noire region, divided into two branches, thereafter encountering the Vilis. The Punus migrated to the Ndendé sector, then returned towards Mouila and were diverted towards Mayombe. Pygmy populations are absent in the Complex even though they often preceded the Bantu people in their migrations (MENIPN 1983). The local populations practice agriculture, hunting, fishing, and forest products gathering for medicine and other needs (construction, palm wine, etc.)

Six villages are located in the Monts Doudou region: Mourindi, Moukoualou, Batsiengui, Boutembi, Igotchi and Digoudou. While the first five villages are located on the periphery of the protected area, Digoudou is located in the middle. The total number of inhabitants recorded in these 6 villages is about 600. Subsistence of the local population is intimately linked to natural resources such as wild animals and forest products. Gathering forest products requires journeys of up to 15 km (Blaney et al. 1998). The principal diet is based on agricultural products, principally plantain bananas, cassavas and manioc, sweet potatoes, corn, and yams. Every dry season, for a period of approximately two weeks, the people of Moukoualou and Mourindi fish in the meres situated in the Domaine de Chasse of Moukalaba and in the AERF of Monts Doudou (Blaney et al. 1998). Monts Doudou is additionally exploited for economic issues by a forester based near Igotchi who exploits the forest on the basis of a permit that expired in 1999.

<center>METEOROLOGY</center>

Climate
Monts Doudou region receives a high level of solar radiation because of its proximity to the equator. The climate is hot and humid. The temperature varies between 17°C and 23°C in the dry season and between 25°C and 32°C in the wet season, with highest temper-

<center>7</center>

atures usually occurring between March and May. The climate is characterized by four distinct seasons:

a rainy season from September to December;

a short dry season of around one month duration between December and February;

a rainy season from February to May;

a dry season from June to September, during which there is extensive cloud cover.

The available data on precipitation for the last 10 years are from the Rabi and Gamba petrol stations operated by Shell Gabon (Figs. 2, 3). Given the short time frame of data collection, a robust analysis of average annual precipitation is not possible. However, the greatest rainfall in the last 10 years was observed in 1977 (2966 mm in Gamba and 2851 mm in Rabi). The driest years during the same 10-year period were in 1993 for Gamba (1615 mm) and 1992 for Rabi (1476 mm). According to the classification of climates by Koppen modified by Trewartha, Monts Doudou is situated in the humid tropical climate of type Aw defined by the alternation of rainy and dry periods with a rainy season during the austral summer (Money 1982). During the rainy season, convection currents can establish thunderclouds 10 km in diameter with a duration generally not exceeding 1 to 2 hours (Shell Gabon 1993). The force of these currents may uproot trees.

The rate of annual evaporation in the study area is around 1200 mm (McGregor and Nieuwolt 1998), which corresponds to half the annual precipitation and reflects the important role of relative humidity (Table 1). Temperature is uniform throughout the year with the coolest months during the dry season.

For 80% of the time, wind speed at Gamba is never greater than 5 m/s and direction is usually from the southeast (Shell Gabon 1993), with occasional winds from the south and southwest. They correspond to the trade wind, which drives the Benguela Ocean current along the coast towards the equator and is the principal cause of sand deposition along the coast. Although no weather data is available further inland, wind force seems to be reduced with distance from the coast.

TABLE 1. Average monthly temperature and relative humidity.

Month	Temperature (°C)	Relative humidity (%)
January	26.3	87
February	26.5	86
March	27.0	86
April	27.1	86
May	26.2	87
June	23.8	85
July	22.4	84
Augurst	22.8	90
September	23.9	–
October	25.0	–
November	25.3	–
December	25.7	–
Annual	25.2	86

Source: Lemoalle and Albaret 1995

Précipitations à Gamba 1990 - 2000

▨ 1990 (2232 mm)	▨ 1991 (2087 mm)	▣ 1992 (1738 mm)	▢ 1993 (1615 mm)
▨ 1994 (1639 mm)	▨ 1995 (2476 mm)	▨ 1996 (1961 mm)	▢ 1997 (2966 mm)
▨ 1998 (2386 mm)	▨ 1999 (2074 mm)	▨ 2000 (1113 mm)	
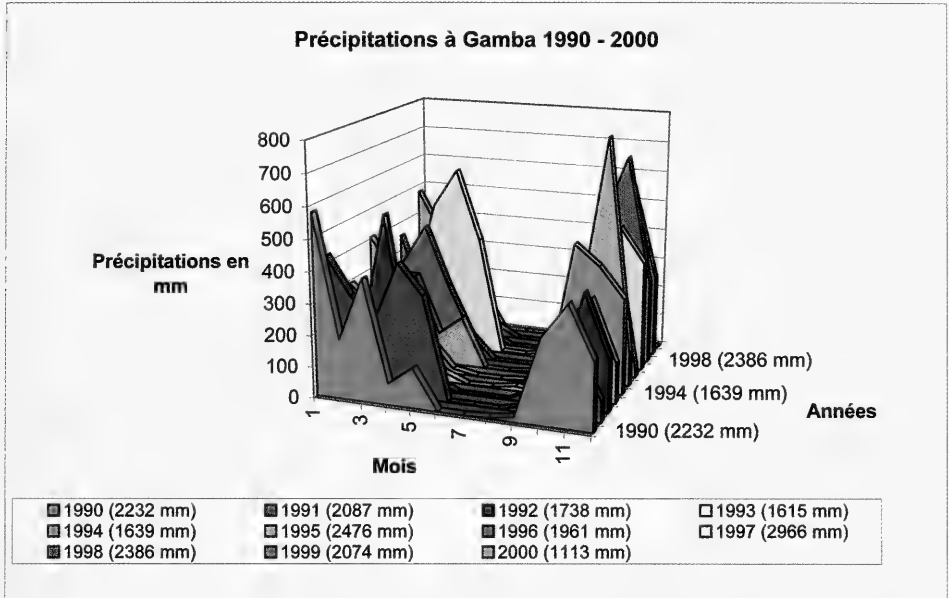
FIGURE 2. Précipitations à Gamba de 1990 à 2000.

Précipitations à Rabi de 1990 à 2000

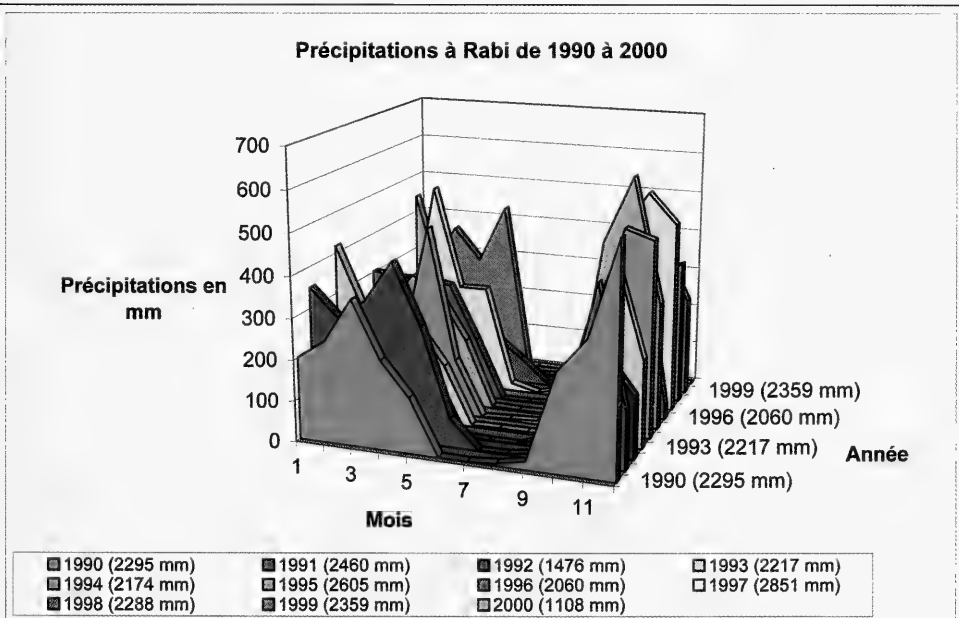|			
▨ 1990 (2295 mm)	▨ 1991 (2460 mm)	▣ 1992 (1476 mm)	▢ 1993 (2217 mm)
▨ 1994 (2174 mm)	▨ 1995 (2605 mm)	▨ 1996 (2060 mm)	▢ 1997 (2851 mm)
▨ 1998 (2288 mm)	▨ 1999 (2359 mm)	▨ 2000 (1108 mm)	

FIGURE 3. Précipitations à Rabi de 1990 à 2000.

Meteorological parameters related to orography

One of the principal abiotic factors influencing variation along elevational gradients is a shift in meteorological parameters related to orography (Riehl 1979). These factors include rain shadows, zones of higher rainfall and decreased solar radiation associated with regular cloud caps, and shifts in daily temperatures (Pendry and Proctor 1996). In turn, variation in these factors regulate water supply — drought or water logging, decomposition rates, soil nutrients, etc., and these parameters have direct bearing on environmental complexity and ecological productivity (Rosenzweig 1992).

Little information is available from the Congo Basin region on variation in climatological variables along mountain slopes. Further, since one of the goals of our Monts Doudou inventory was to examine biotic changes related to altitudinal variation and the fact that the activity patterns of many of the surveyed organisms are directly related to factors such as rainfall and temperature, meteorological information was gathered during the course of the February–March 2000 biological inventory of Monts Doudou to address these points.

Meteorological data collected included daily minimum and maximum temperatures, using a min-max thermometer, and precipitation, using a standard rain gauge. These devices were installed within a few hours of arriving at each campsite. The rain gauge was placed in an open area without canopy cover and the thermometer attached to the trunk of a

TABLE 2. Summary of minimum and maximum temperatures and precipitation during the 1999 expedition to Monts Doudou. Meteorological information was also obtained at the 110-meter site during the same period as the 350-meter and 625-meter sites.

Periods of measurement within each transect	Temperature (°C)[1]		Rainfall[2] (mm)
	Minimum	Maximum	
24 Feb.–4 March			
110 m	10, 20–24	10, 28–29	6, 25–22.5
	22.0 ± 0.33	28.2 ± 0.15	7.4 ± 2.89
5–13 March			
350 m	9, 20–22	9, 24–27	4, 3–45.0
	20.9 ± 0.20	26.3 ± 0.33	9.8 ± 5.25
110 m	6, 21–24	6, 25–30	2, 95–11.7
	22.3 ± 0.42	28.3 ±0.71	
14 – 22 March			
625 m	9, 18–22	9, 24–26	6, 1.0–80.0
	20.1 ± 0.39	24.9 ± 0.26	14.3 ± 8.85
110 m	9, 22–24	9, 27–30	2, 12.7–19.4
	22.9 ± 0.32	28.8 ± 0.33	

[1]Data are presented as number of records, range, mean, and ± standard deviation.
[2]Data are presented as number of days with rain, range, mean, and ± standard deviation.
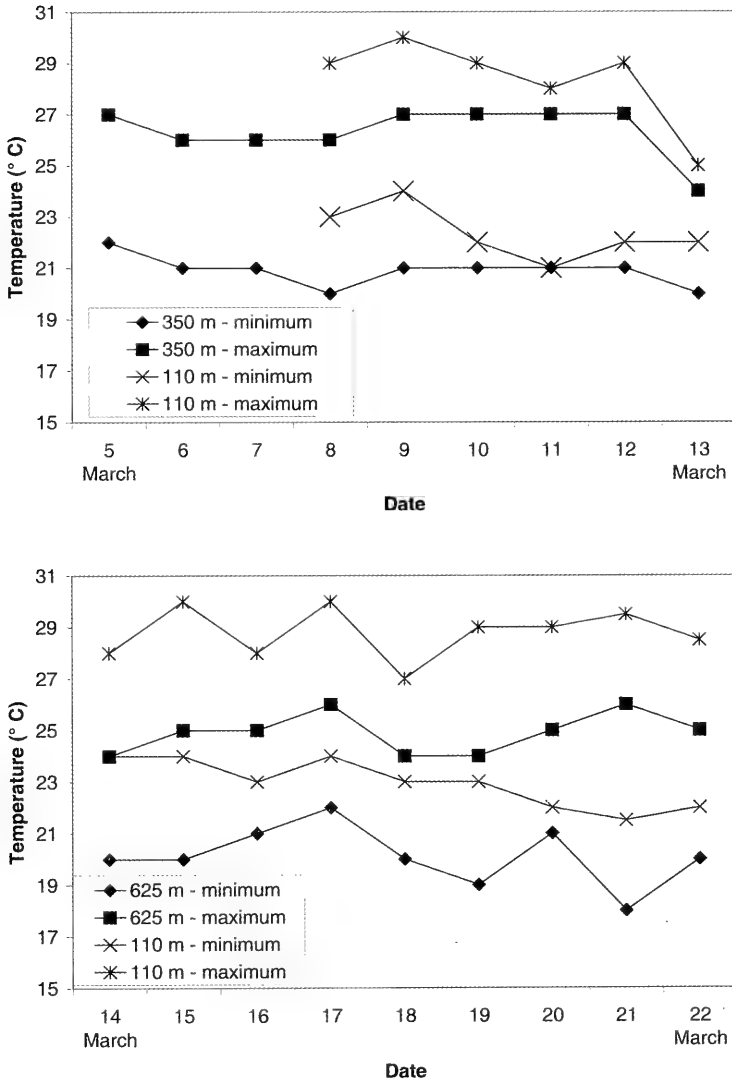
FIGURE 4. Comparison of minimum and maximum average daily temperatures during simultaneous periods in the 110 and 350 m zones (a) and 110 and 625 m zones (b)

tree (without epiphytic growth) in the shade. Readings were made each morning between 8:30 and 10:00 a.m.

Within a few days after our departure from the 110-meter site the research group of Marc Colyn installed a weather station adjacent to our joint study area within that elevational zone. Data from this station, which were obtained by Violaine Nicolas during the period we were at higher elevations, allows comparison of simultaneous weather patterns on the mountain between different elevational zones.
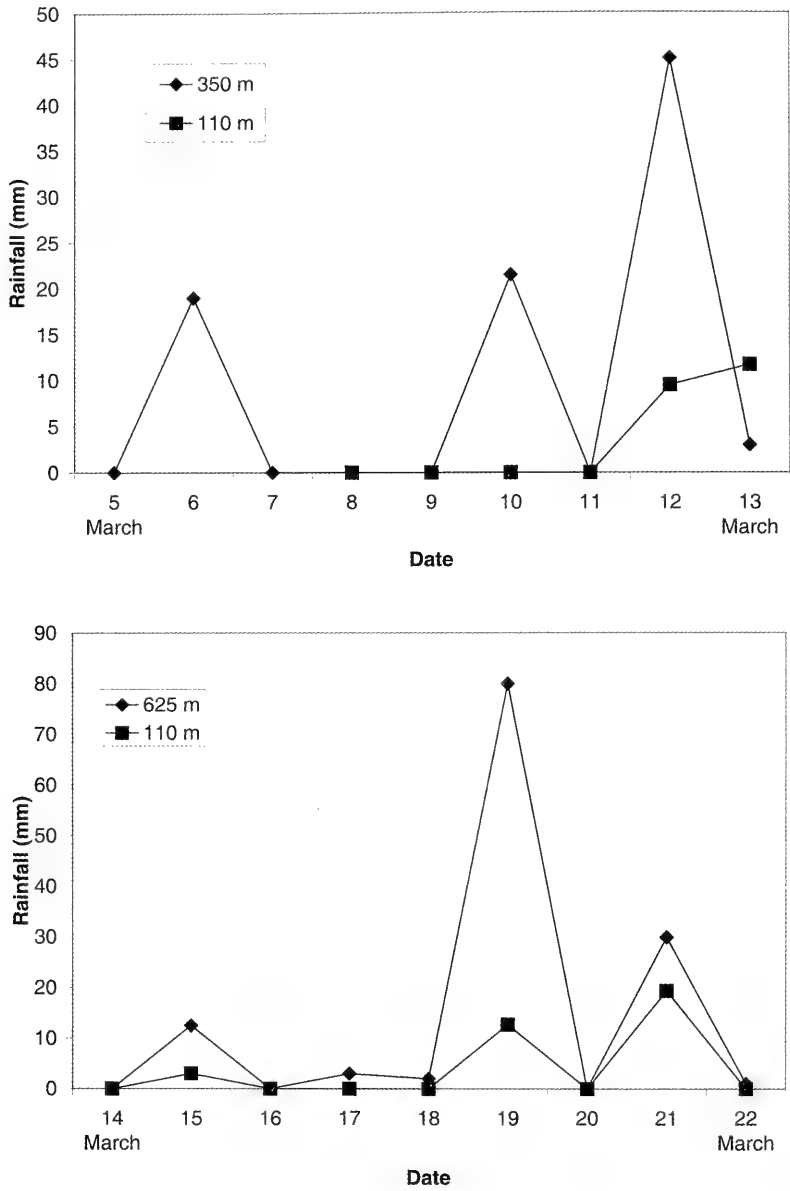
FIGURE 5. Comparisons in daily rainfall during simultaneous periods between the 110 and 350 m zones (a) and 110 and 625 m zones (b).

Variation along elevational gradient

There was a clear decrease in the minimum daily average temperature with increasing altitude from 22.0°C at 110 m to 20.1°C at 625 m. Further, the average maximum temperature was higher at the lowest elevation and decreased with altitude from 28.2°C at 110 m to 24.9°C at 625 m (Table 2).

The pattern of increasing average minimum and maximum temperatures during the period of the inventory, from 24 February to 22 March, was established for the 110-meter

contour. The maximum average daily temperature at 110 m was 28.2° C between 24 February and 4 March, 28.3° C between 5 and 13 March, and 28.8° C between 14 and 22 March. The same pattern holds for average minimum temperature. Thus, during the course of this field trip there was a slight increase in daily temperatures within a single elevational zone. The factors of altitude and season played a role in measured changes in weather patterns. However, during the four weeks we were in the field the shift in average minimum and maximum average temperatures was greater between elevational zones than the seasonal shift at the 110-meter site.

The number of days of rainfall between elevational zones was rather consistent, with precipitation occurring 44-67% of the days we were at each site (Table 2). However, the average number of millimeters per rain shower, as well as the maximum amount during any 24-hr period, increased steadily with altitude. Total rainfall was 74.0 mm at 110 m (24 February to 4 March), 88.5 mm at 325 m, and 128.5 mm at 625 m. At 110 m the three most rainy 24-hour periods were 22.5, 22.0, and 14.5 mm, at 350 m 45.0. 21.5, and 19.0 mm, and at 625 m 80, 30, and 12.5 mm. In general most of the showers occurred in the later portion of the day, evening or night. Only on a few occasions did we experience rain during the morning or early afternoon.

Variation along the slopes of Monts Doudou

Data obtained from the meteorological station at the 110 m site while we surveyed higher elevations provide a means to understand how weather patterns vary along the slopes of Monts Doudou. The data from the 110 m zone were separated according to the periods that we were working at the 350-meter and 625-meter zones (Table 2). Average minimum and maximum daily temperatures were higher at 110 m than in the 350-meter zone (Fig. 4a) and the 625-meter zone (Fig. 4b).

Twenty-four hour periods with rainfall at the 110-meter and 350-meter sites between 5 and 13 March showed few parallels (Fig. 5a). No rain fell at the former site until the end of this period, while at the latter there was precipitation at least every other day. This is in contrast to the 625-meter and 110-meter sites between 14 and 22 March, which showed coinciding periods of rainfall, although the magnitude was always less in the 110-meter zone (Fig. 5b).

Thus, rain showers reaching the mountain tend to deposit more precipitation at higher altitudes. Sometimes these systems are widespread and at other times rather isolated. Even though there was some seasonal change in temperature during the period of our inventory, the most notable shift was related to elevation. On the basis of the meteorological data gathered it is clear that an altitudinal deviation of slightly over 500 m between the lowest and highest survey sites on Monts Doudou shows important differences in weather patterns and in turn differences could be expected in the biotic communities along this elevational gradient.

APPENDIX 1

PARTICIPANTS IN THE PROJECT (FIELD AND LABORATORY)

A total of 16 field workers and scientists took part in this multidisciplinary study, including field participants as well as researchers participating in the analysis of collections. The names and addresses of all scientific participants follow:

Barrière, P., UMR-CNRS 6552, Univerrsité de Rennes 1, Station Biologique, F-35380 Paimpont, France

Bourobou Bourobou, H., P., Herbier National du Gabon, IPHAMETRA - CENAREST, B.P. 1156, Libreville, Gabon

Branch, W. R., Department of Herpetology, Port Elizabeth Museum, P.O. Box 13147, Humewood 6013, South Africa

Burger, Marius, Life Sciences Division, South African Museum, P.O. Box 61, 8000 Cape Town, South Africa, and Avian Demography Unit, University of Cape Town, Rondebosch 7701, South Africa

Channing, A., Department of Zoology, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa

Colyn, M., UMR-CNRS 6552, Univerrsité de Rennes 1, Station Biologique, F-35380 Paimpont, France

Fisher, Brian L., Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118

Goodman, Steven M, Field Museum of Natural History, Roosevelt Road at Lake Shore Drive, Chicago, Illinois 60605, USA, and WWF, B.P. 738, Antananarivo (101), Madagascar

Guimondou, S., Direction de la Faune et de la Chasse, B.P. 1128 Libreville, Gabon

Hutterer, R., Zoologisches Forschungsinstitut und Museum Koenig, Adenauerallee 160, D-53113 Bonn, Germany

Koopman, W. J. M., Biosystematics Group, Wageningen University, Generaal Foulkesweg 37, 6703 BL Wageningen, The Netherlands

Nicolas, V., UMR-CNRS 6552, Univerrsité de Rennes 1, Station Biologique, F-35380 Paimpont, France

Patrice Christy, Patrice, BP 2240 Libreville, Gabon

Sosef, M. S. M., Herbier National du Gabon, IPHAMETRA-CENAREST, B.P. 1156, Libreville, Gabon. Current address: Biosystematics Group, Wageningen University, Generaal Foulkesweg 37, 6703 BL Wageningen, The Netherlands

Thibault, M., World Wildlife Fund, Central Africa Regional Program Office, thibaultmjt@hotmail.com

Van Noort, Simon, Curator of Entomology, Life Sciences Division, South African Museum, P.O. Box 61, 8000 Cape Town, South Africa

Literature Cited

BLANEY, S., S. MBOUITY, J. M. NKOMBÉ, AND M. THIBAULT. 1997. Caractéristiques socio-économiques des populations des départements de Ndougou et de la Basse-Banio. World Wildlife Fund, Central Africa Regional Program Office, Libreville, Gabon. 75 pp.

BLANEY, S., S. MBOUITY, P. MOUSSOUNDA NZAMBA, AND J. M. NKOMBÉ. 1998. Caractéristiques socio-économiques du département de la Douigny et de Louango (Département de la Mougoutsi). World Wildlife Fund, Central Africa Regional Program Office, Libreville, Gabon. 74 pp.

BLANEY, S., O. MBOUMBA MAVOUNGOU, S. MBOUITY, P. MOUSSOUNDA NZAMBA, J. M. NKOMBÉ, NSAFOU LOEMBÉ AND J. TONDANGOYE. 1998. Caractéristiques socio-économiques du département d'Étimboué. World Wildlife Fund, Central Africa Regional Program Office, Libreville, Gabon. 56 pp.

ENVIRONMENTAL RESOURCES MANAGEMENT. 1999. Impact assessment of the Bilinga concession seismic programme: Gabon. Shell Gabon. 183 pp.

LEMOALLE, J. AND J. J. ALBARET. 1995. Vevy lagoon and Ndogo lagoon: an environmental appraisal. ORSTOM et Shell Gabon. 18 pp.

MBOUMBA MAVOUNGOU, O., P. MOUSSOUNDA NZAMBA, J. M. NKOMBÉ, AND S. BLANEY. 1999. Caractéristiques socio-économiques des villages de Digoudou, de Dougandou, de Diboumba, de Nzienzili et de Païlou. World Wildlife Fund, Central Africa Regional Program Office, Libreville, Gabon. 30 pp.

MCGREGOR, G. R. AND S. NIEUWOLT. 1998. Tropical Climatology, 2nd edition. John Wiley, New York. 339 pp.

MINISTÈRE DE L'ÉDUCATION NATIONALE AND INSTITUT PÉDAGOGIQUE NATIONALE (MENIPN). 1983. Géographie et cartographie du Gabon. Paris. 135 pp.

MONEY, D.C. 1982. Climate, soils and vegetation. University Tutorial Press, London. 272 pp.

MPEAT. 1993. Recensement général de la population et de l'habitat. Principaux résultats. République gabonaise. Ministère de la planification, de l'économie et de l'aménagement du territoire. Libreville, Gabon. 96 pp.

OLSON, D. M. AND E. DINERSTEIN. 1998. The global 200: a representation approach to conserving the earth's most biologically valuable ecoregions. Conservation Biology 12:502-515.

PENDRY, C. A. AND J. PROCTOR. 1996. The causes of altitudinal zonation of rain forests on Bukit Belalong, Brunei. J. of Ecology 84:407–418.

RIEHL, H. 1979. Climate and weather in the tropics. Academic Press, London. 611 pp.

ROSENZWEIG, M. L. 1992. Species diversity gradients: We know more and less than we thought. J. of Mammalogy 73:715–730.

SHELL GABON. 1993. Rabi Phase II Environmental Statement. N. p.

Botanical Diversity of the Pleistocene Forest Refuge Monts Doudou

M. S. M. Sosef[1], Y. Issembe[2], H. P. Bourobou Bourbou[2], and W. J. M. Koopman[1]

[1]*National Herbarium of the Netherlands*
Biosystematics Group, Wageningen University
Generaal Foulkesweg 37
6703 BL Wageningen, The Netherlands

[2]*National Herbarium of Gabon*
R.D. 1135, Libreville, Gabon

To improve our knowledge of the flora and vegetation of the Monts Doudou Reserve within the context of the development of a management plan, the National Herbarium of Gabon has performed two types of research: a general botanical inventory and a botanical plot inventory. Within the Monts Doudou Reserve the following vegetation types can be recognized: savannah, dry land lowland forest, lowland swamp forest, gallery forest, medium altitude forest and high altitude forest. The number of botanical specimens collected in the Reserve was 2459, representing 991 different species. Besides, 5 species endemic to the Monts Doudou have been identified; 9 others have a very limited distribution in the southwest of Gabon. A percentage of 11% of the observed species is endemic to the zone (surface area of distribution less then 150,000 km^2). The hypothesis that Monts Doudou represents a former Pleistocene forest refuge is approved and strengthened. A biodiversity analysis based upon 11 families shows that the zones with a very high botanical biodiversity are situated at medium and high altitude. A positive correlation has been demonstrated between altitude and vegetation diversity (species number and number of stems per surface unit), which is true for the woody flora as well as for the numerous non-woody species. Complementary botanical inventories of the high altitude zones of the Monts Doudou are strongly recommended.

RÉSUMÉ

Pour améliorer notre connaissance de la flore et la végétation de la Réserve des Monts Doudou dans le cadre du développement d'un plan d'aménagement, l'Herbier National du Gabon a exécuté deux types de recherches: un inventaire botanique général et un inventaire botanique par parcelles. Dans les Monts Doudou, on peut reconnnaître les formations végétales suivantes: savanes, forêt de basse altitude en terre ferme, forêt de basse altitude marécageuse, forêt galeries, forêt de moyen altitude et forêt de haute altitude. Le nombre d'échantillons botaniques récoltés dans la Réserve est évalué à 2459, et ceux-ci représentent 991 espèces différentes. Par ailleurs, on a identifié 5 espèces de plantes limitées aux Monts Doudou; 9 autres de distribution très limitée dans le Sud-Ouest du Gabon. Un taux de 11% des espèces observées est endémique pour la zone (surface de l'aire de distribution de moins de 150,000 km^2). L'hypothèse selon laquelle les Monts Doudou représentent un ancien refuge forestier du Pléistocène, est approuvée et renforcée. Une analyse de la biodiversité à partir de 11 familles montre que les zones ayant une biodiversité

botanique très élevée se trouvent en moyenne et haute altitude. Une corrélation positive a été montrée entre l'altitude et la diversité de la végétation (nombre d'espèces et pieds par unité de surface), et cela est d'autant plus vrai pour la flore ligneuse que pour les nombreuses espèces non ligneuses. Des inventaires botaniques complémentaires des zones de haute altitude des Monts Doudou sont vivement recommandés.

<div align="center">INTRODUCTION</div>

A thorough knowledge of the flora of a certain region acts as an indispensable basis for all other environmental research, including ecological studies, forestry, economic botany, and issues of conservation and management. Although Gabon, with an estimated total of 7000 plant species, possesses a tropical lowland flora known to be the richest in all of Africa (Breteler 1996), unfortunately we must note that its flora is at the same time among the least well-known ones, and much remains to be done. At the national level there are numerous regions within Gabon that are imperfectly or not at all known botanically, because of a largely insufficient number of botanical collections. [An estimated total of only 70,000 specimens (Breteler 1996) was collected in this country that has a surface of 262,000 km^2.] The Monts Doudou were amongst these imperfectly known areas, with only about 1200 botanical collections.

In order to draw up a proper management plan for the Reserve, it was recognized that a more detailed knowledge of the flora in general, the types of vegetation, and the distribution of botanical diversity within the reserve was desirable. The National Herbarium of Gabon was approached to perform such studies, which led to the present results. Two different types of research were performed: firstly, a general botanical inventory, and secondly an inventory of small plots. In both, the question whether altitude was related to botanical diversity was addressed.

<div align="center">OBJECTIVES</div>

General botanical inventory

In the past, the Monts Doudou have been visited by several botanists, most notably Dutch (see Table 2), who made 1235 herbarium collections. Before the present project started, data on only a few hundred of these collections were available in the database kept at the National Herbarium of Gabon.

The Monts Doudou have a surface area of 3320 km^2. An average of 2 collections per square kilometer is a figure generally accepted by botanists to consider a tropical region as being "botanically well-known" (Campbell and Hammond 1989). With the present means and work program it was impossible to arrive at the preferred number of approximately 6,500 collections for the Monts Doudou, but our aim was to at least double the number of available plant collections. With a total of around 2,500 collections, the Monts Doudou would enter the category of "botanically fairly well-known," which is acceptable for the moment.

Besides that, the following four objectives were formulated for the general botanical inventory: 1. To arrive at a species list for the Monts Doudou Reserve; 2. To develop a standardized method of botanical diversity analysis; 3. To investigate the relationship between altitude and botanical diversity; 4. To indicate the most important localities in terms of botanical diversity conservation.

Plot inventory

The objective of the botanical inventory of small plots was to obtain information on forest vegetation composition, and on botanical diversity as a function of altitude. This would allow a comparison between our data and those obtained by other, mainly zoological, researchers, who performed their research within the context of the same project.

Before the actual inventory, the National Herbarium of Gabon foresaw the verification of a correlation between botanical diversity and the different vegetation types of the Monts Doudou, as given on an existing vegetation map. Unfortunately, this map proved not to be detailed enough (primary forest divided into "accessible forest" and "inaccessible forest") for this type of analyses.

<div align="center">METHODS</div>

General botanical inventory

Planning of the missions. Using the existing vegetation map and given the possibilities offered by road conditions and logistics, the localities to be visited were identified. To obtain a maximum of botanical diversity information, these sites were well distributed among the various vegetation types. We identified six different vegetations to be visited: "dry savannah," "riverine forest," "lowland forest on dry land," "lowland swamp forest," "mid-altitude forest," and "high-altitude forest."

In order to locate as many species as possible in their fertile state (with flowers or fruits), it was decided to distribute the various missions well throughout the project period.

Biodiversity analysis. The term "biodiversity" is a complex one. The biodiversity of a certain region is often expressed by the number of species present. Because this simple formula is often not satisfactory (a given region may comprise a similar number of species than another one, but with a much higher percentage of rare species), researchers have developed other indexes. These indexes often imply the definition of categories of species rarity and/or threat. The most well known of these is probably that of the IUCN (IUCN, 1994), serving as a basis for most of the "Red Data Lists."

In Gabon, the level of our botanical knowledge is, unfortunately, still too low for the application of the IUCN categories. Another, more simple and coarse, system has been developed for Ghana by W. D. Hawthorne (Hawthorne and Abu Juam 1995) and was tested and adapted during several field studies in Ghana. It is this system that the National Herbarium of Gabon has adapted for Gabon within the context of the present project. A total of nine rarity categories have been defined, each with its own biodiversity value (Table 1). For this biodiversity analysis we have chosen 11 plant families with a significant number of species occurring in Gabon and botanically more or less well-known.

Indicator species for a Pleistocene forest refuge. In the past, a group of *Begonia* species (sections *Loasibegonia* A.DC. and *Scutobegonia* Warb.) were identified as indicators for the presence of a forest refuge during the Pleistocene (Sosef 1994). During the botanical inventories, these species were given special attention as their presence may strengthen the hypothesis that the Monts Doudou represent a former forest refuge area.

Plot inventory

To collect data on vegetation composition and species diversity we have established plots of 40 × 40 m. Within these plots all trees with a stem diameter of 10 cm and over were taken into account; the species name and the number of stems present per species were

TABLE 1. Review of rarity categories and their attributed biodiversity values.

Category	Distribution	Rarity within distribution area	Biodiversity value
1A	Endemic species with a very limited distribution (< 150,000 km^2). Gabon has a strong responsibility regarding the protection of this species.	Rare	81
1B	Same distribution	Common or fairly common	27
2A	Species limited to Lower Guinea (biogeographic region recognized by White (1979) that extends from southeast Nigeria to the west of the Democratic Republic of Congo). Gabon has a certain responsibility regarding the protection of this species.	Rare	27
2B	Same distribution	Common or fairly common	9
3A	Species limited to Upper Guinea and Lower Guinea (Liberia to the west of the Democratic Republic of Congo) or limited to Lower Guinea and Congolia (southeast Nigeria to the east of the Democratic Republic of Congo, Rwanda, and Burundi). Paying attention to the protection of this species may be favorable for Gabon.	Rare	9
3B	Same distribution	Common or fairly common	3
4A	Species limited to Lower Guinea, Congolia, and East Africa, or to Upper Guinea, Lower Guinea, and Congolia.	Rare	3
4B	Same distribution	Common or fairly common	1
5	Species with a larger distribution area	–	1

noted down. From these data, we obtained for each of the plots: the number of tree families, the total number of tree species, the average number of tree species per family, and the total number of stems. The objective was to establish at least 15 plots, so as to arrive at a total surface of about 2.5 hectare. Because we wanted to study the relation of various parameters with altitude, the plots were chosen so as to represent a wide range of altitudes.

Similar to the zoological research, three altitudinal zones were defined:

Low altitude: < 200 m

Medium altitude: 200–450 m

High altitude: > 450 m

The objective was to establish at least five plots per altitudinal zone.

Within each 40 × 40 m plot, a subplot of 10 × 10 m was selected in which the presence of every plant species was recorded. A reference herbarium specimen was collected for almost every species encountered.

Differences between the plot means per altitudinal zone were tested on significance using one way ANOVAs and Tukey-Kramer HSD multiple comparison tests in Jump 3.1.4 (SAS Institute Inc., NC, USA).

The actual correlations of plot altitude with number of tree families, total number of tree species, number of tree species per family, number of stems (all in the 40 × 40 plots), and total number of species (in the 10 × 10 plots) were examined using regression analyses. The analyses were performed in Excel 97 (Microsoft Corporation, USA). Pearson's correlation coefficients corresponding to the regression lines were calculated and tested on significance using Jump 3.1.4.

<center>RESULTS AND ANALYSES</center>

General botanical inventory

Realization of the missions. Botanical collections were gathered during the following periods:

16–27 March 2000
 4–19 April 2000
14 May–4 June 2000
14–27 September 2000

Figure 1 shows the location of all visited sites. Because the exact boundaries of the Monts Doudou Reserve were not known at the start, and even changed during the project, some of these localities are situated outside the actual reserve.

The available collections. During the field missions 1286 collections were gathered, 1254 inside the Monts Doudou Reserve. Data on all these collections were entered in the database of the National Herbarium of Gabon, using the BRAHMS software (Filer 1999). In general, each collection comprised four or five duplicates to be distributed to other herbaria in Africa, Europe, and the United States.

At the start of the present project, data on 232 collections from the Monts Doudou Reserve were already available from the database. The Biosystematics Group (Wageningen University, The Netherlands), one of the principle partners of the National Herbarium, provided photocopies of field annotations and identifications of 1099 collections gathered from the Monts Doudou. They were all entered within the context of this project. Data on another 106 collections originating from the Monts Doudou were supplied by the Missouri Botanical Garden (St. Louis, United States), another partner of the National Herbarium. Lee White (World Conservation Society, Lopé Reserve, Gabon) put data on another 33 collections at our disposition. The latter, however, were not yet identified down to species level and were therefore not taken into consideration.

At present, a total of 2459 botanical collections relating to the biodiversity of the Monts Doudou are recorded in our database. To make a geographical selection of the data, we have used the limits of the nine rectangles presented in Figure 2. Below, a synoptic table concerning these collections is given (Table 2).

During the inventory of the subplots, around 400 reference samples were collected. After being analyzed, most of these will be incorporated in the collection of the National Herbarium as well. Consequently, we may conclude that our objective to arrive at a total of about 2500 collections for the Monts Doudou has been met with, and that this number will soon be exceeded.

The distribution of the 2459 botanical collections within the Monts Doudou Reserve is presented in Figure 3.

Identification of the collections. Personnel of the National Herbarium have identified the majority of the new collections. About a third were identified by specialists of Wageningen University and by G. Achoundong (National Herbarium of Cameroon,

<center>21</center>

FIGURE 1. Sites where botanical specimens were collected during the project.

FIGURE 2. The nine rectangles used to select the data related to botanical collections.

TABLE 2. Overview of all available botanical collections (2459) of the Monts Doudou Reserve.

Collector	Number of collections	Collecting date
J. C. Arends et al.	118	Dec 1984
M. A. van Bergen et al.	14	Jan. 1996
H. P. Bourobou Bourobou et al.	283	Sept. 2000
J. J. Dibata	6	?
Y. Issembé et al.	125	May-June 2000
A.M. Louis	1	Oct. 1986
G. McPherson	81	May 1997
J. M. Reitsma et al.	589	May 1985–April 1987
M. S. M. Sosef et al.	846	March–Sept. 2000
J. J. F.E. de Wilde et al.	375	Nov.–Dec. 1986, March 1988
C. Wilks	21	April 1987

Yaoundé). Within the framework of this project, F. J. Breteler (Wageningen University), the world specialist on the flora of Gabon, could stay at the National Herbarium of Gabon for 3 weeks and has been a great help in identifying our specimens.

A total of about 75% of the new collections have been identified to species level. The remaining were identified at genus or family level and await the availability of specialists who can further identify them.

The species concerned. A complete list of all species presently known to occur within the Monts Doudou has been added as Appendix A. This list shows a total of 991 different species (806 Dicots in 92 families, 131 Monocots in 14 families, and 54 ferns in 18 families).

Among these species, 5 are endemic to the Monts Doudou, and another 9 have a very restricted distribution in southwestern Gabon (and neighboring western Congo-Brazzaville). The most remarkable species and discoveries are listed below:

Adhatoda le-testui (Acanthaceae): endemic species with a very limited distribution in southwestern Gabon;

Anthonotha trunciflora (Caesalpiniaceae): rare species, known only from the coastal zone of Gabon;

Begonia dewildei (Begoniaceae): species endemic to the Monts Doudou; we have located another population of this rare species;

Begonia gabonensis (Begoniaceae): recently discovered species endemic to the Monts de Cristal and the Monts Doudou;

Begonia sp. nov. ? (Begoniaceae): probably a new species, close to *Begonia scutulum*, but we need more material to exclude the possibility that the population is of hybrid origin;

Calpocalyx brevifolius (Mimosaceae): recently discovered species and known only from around Tchibanga and the Rabi-Kounga area;

Cincinnobotrys acaulis (Melastomataceae): first record for Gabon; previously known from the south of the RDC, northern Angola and Zambia;

Commitheca letestuana (Rubiaceae): rare species, endemic to southern Gabon;

Connarus longestipitatus (Connaraceae): first record of this species for Gabon;

Costus nudicaulis (Zingiberaceae): rare species, endemic to Gabon;
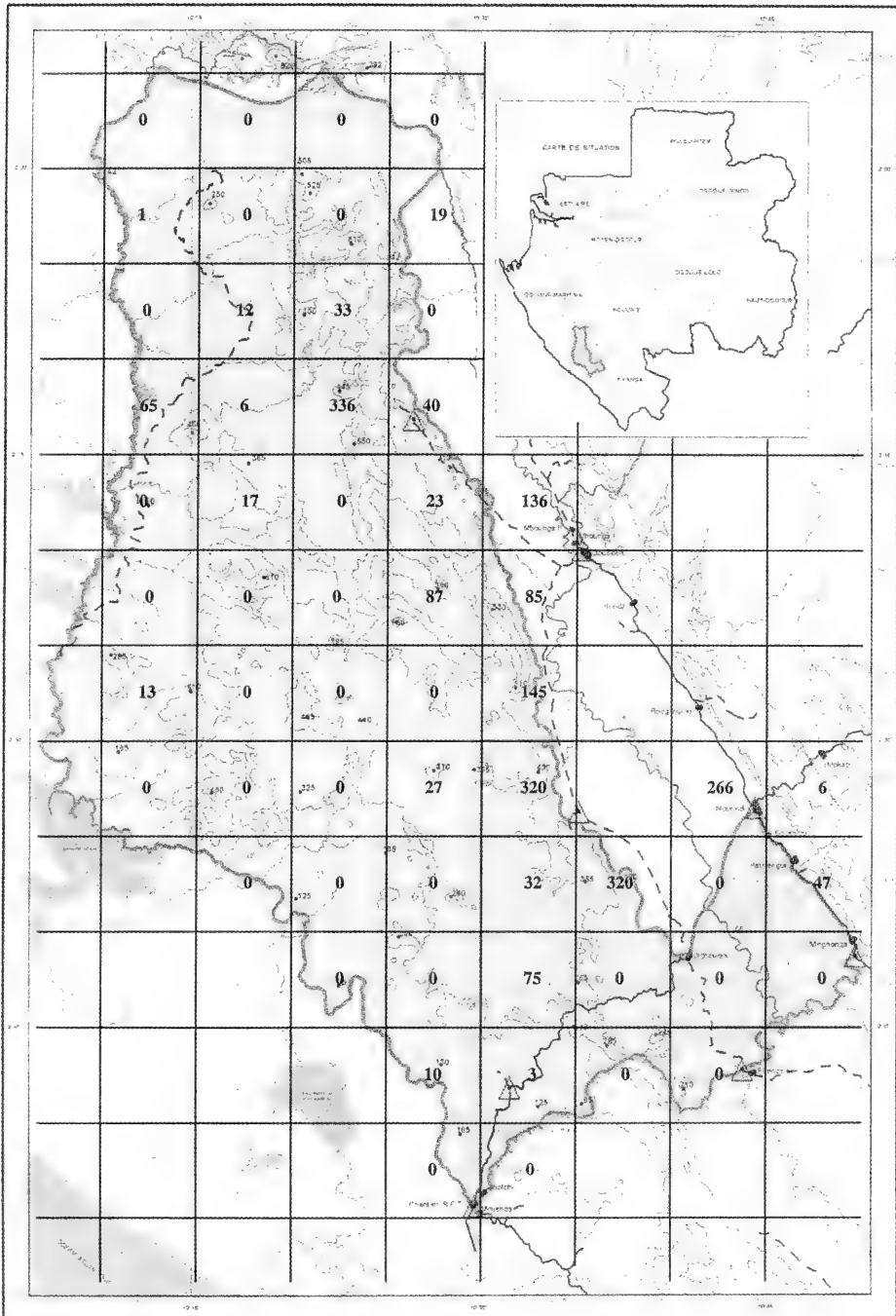
FIGURE 3. The distribution of the 2459 botanical collections within the Monts Doudou Reserve.

Cynometra nyangensis (Caesalpiniaceae): previously known from a single collection by Le Testu around Tchibanga at the beginning of the 20th century;

Dichapetalum sp. nov. (Dichapetalaceae): new species yet to be described, recognised by the specialist F. J. Breteler. A second collection appeared to be present in our herbarium, collected in the Monts Doudou Reserve by Reitsma some 15 years ago.

Elaeophorbia drupifera (Euphorbiaceae): rare species, only known from southern Gabon and western Congo-Brazzaville.

Impatiens floretii (Balsaminaceae): species endemic to the Monts Doudou Reserve;

Isomacrolobium conchyliophorum (Caesalpiniaceae): rare species, endemic to southern Gabon;

Memecylon salicifolium (Melastomataceae): recently discovered species, previously known from some collections around Bélinga (northeastern Gabon);

Saintpauliopsis lebrunii (Acanthaceae): first record of this species for Gabon (but recently also collected on Mount Iboundji); rare species known from Central and East Africa;

Schumanniophyton hirsutum (Rubiaceae): first record of this species for Gabon; species known from Congo-Brazzaville, Angola (Cabinda) and the RDC;

Tapura letestui (Dichapetalaceae): rare species, known only from southwestern Gabon and western Congo-Brazzaville;

Tarenna jolinonii (Rubiaceae): rare species, endemic to Gabon;

Trichoscypha gambana (Anacardiaceae): recently discovered species, only known from the region Gamba-Rabi-Monts Doudou;

Trichostephanus gabonensis (Flacourtiaceae): recently discovered species, endemic to the Monts Doudou;

Tristemma vestitum (Melastomataceae): recently discovered species, previously known from a single collection originating from northwestern Gabon;

Warneckea cauliflora (Melastomataceae): rare species, endemic to southern Gabon and western Congo-Brazzaville.

Biodiversity analysis

A complete biodiversity analysis for the 11 selected families is given in Appendix B. These 11 families correspond to 259 species, which is 26.1% of the total number of species as given in Appendix A.

Table 3 shows the number of species and biodiversity values per family. The total and mean biodiversity values may be compared later on with data obtained from other regions within Gabon, to show the relative importance of the Monts Doudou. Because the method has been recently developed, such a comparison is not yet possible to date.

Four families show a high percentage of rare species: the Balsaminaceae, Begoniaceae, Dichapetalaceae and Melastomataceae. It is remarkable that within the Monts Doudou the Connaraceae and the Orchidaceae are apparently represented by common or fairly common species (see Appendix B for more details).

Furthermore, we would like to know how these biodiversity values are distributed in relation to altitude. Table 4 shows the results of this analysis. Unfortunately, some of the older collections (291 in total) could not be taken into consideration, because the altitude at which they were collected is unknown.

While trying to analyze the figures in Table 4, we noticed that it was only logical to look at the total biodiversity value *in relation to* the number of species (so the mean

TABLE 3. Summary of the number of species and biodiversity values per family.

Family	Number of species	Total biodiversity value	Mean biodiversity value
Acanthaceae	27	187	6.93
Apocynaceae	29	255	8.79
Balsaminaceae	5	121	24.20
Begoniaceae	24	358	14.92
Caesalpinaceae	56	582	10.39
Combretaceae	8	40	5.00
Connaraceae	17	39	2.29
Dichapetalaceae	17	227	13.35
Mimosaceae	19	140	7.37
Melastomataceae	29	508	17.52
Orchidaceae	28	70	2.50
Total	259	2527	9.76

biodiversity value) *and* to the number of collections made per zone. The mean biodiversity value gives an indication of the percentage of rare species encountered, whereas the number of collections is indicative of the thoroughness of the inventory (of the altitudinal zone concerned), and therefore for the likelihood that the total biodiversity value will still increase after additional collecting efforts. We should realize that this could be seen as a drawback of the present methodology: the total biodiversity value can hardly serve as a figure on its own, and should be studied in relation to other data.

Taking into account all data in Table 4, we may conclude that the altitudinal zone of 300 to 700 m is clearly the richest part of the Monts Doudou. Furthermore, it is most likely that a more thorough inventory of the zone above 500 m will yield many more rare species. Following such inventory work, the total biodiversity value of this zone will increase, probably even beyond that of the 400–499-meter zone. It is remarkable that the 500–599-meter zone appears to be the zone with the highest percentage of rare species, but still has very few collections. Could this be explained by a sampling methodology? Is a botanist, struggling on her/his way to the summit, reluctant to stop and collect anything, except when it appears to be something special?

TABLE 4. Analysis of the distribution of biodiversity values in relation to altitude, and the number of collections per altitudinal zone. Rare species refer to rarity categories 1A, 1B, and 2A.

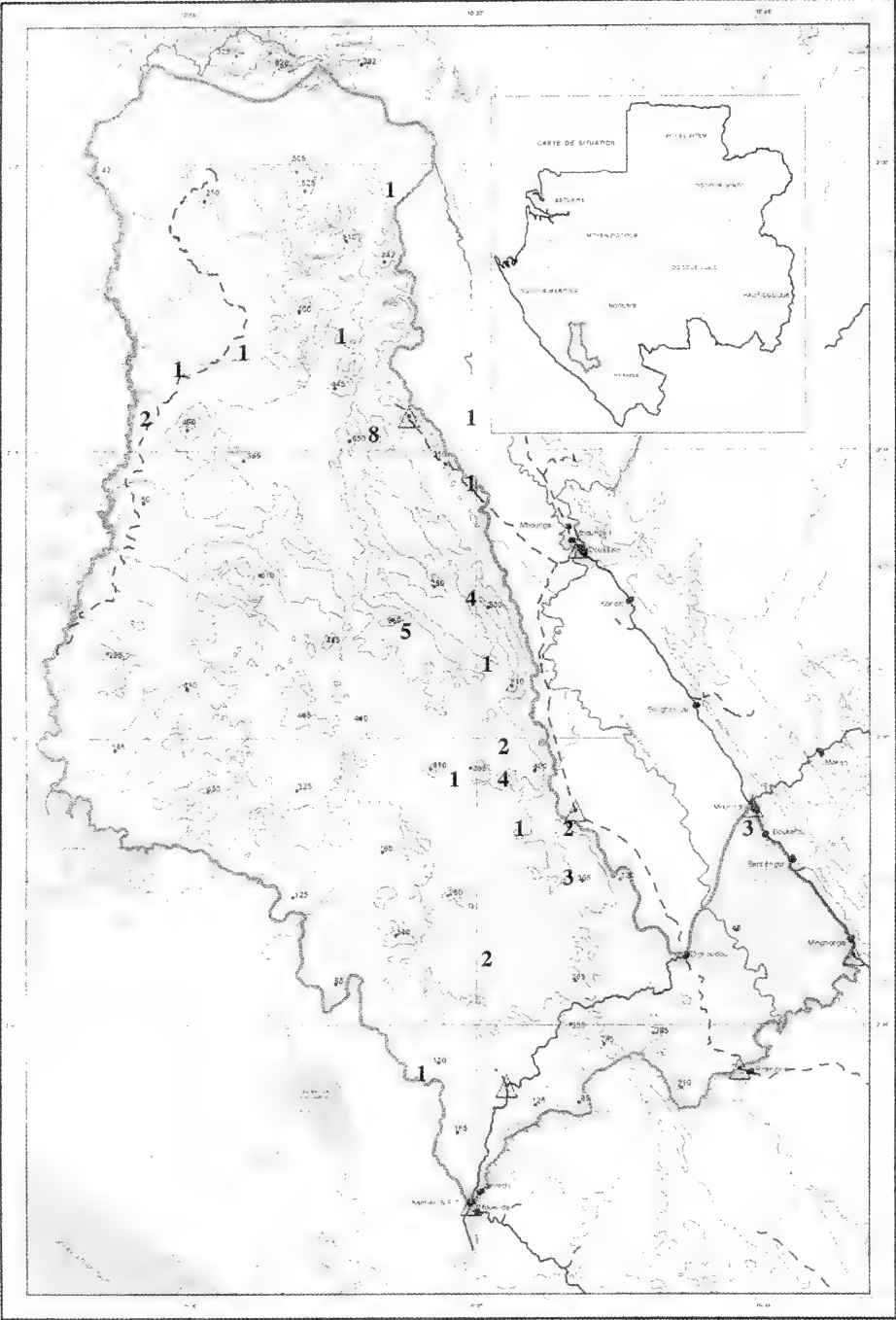| Altitude (m)	Number of species	Number of rare species	Total biodiversity value	Mean biodiversity value	Number of collections
0–99	16	1	106	6.62	128
100–199	87	5	465	5.34	711
200–299	61	4	435	7.13	366
300–399	44	7	437	9.93	232
400–499	61	9	711	10.50	444
500–599	45	7	505	11.22	128
600–700	49	8	453	9.24	161

FIGURE 4. Distribution of the number of endemic and rare species (categories 1A, 1B, and 2 A) at specific sites.

Figure 4 shows the specific localities with concentrations of rare species, hence the sites with highest biodiversity figures. Clearly, the two hills that were visited (Mont Pongou at 2°14'S, 10°23'E, and Mont Mougoubi at 2°24'S, 10°26'E) are the richest sites. This even notwithstanding the fact that the last one has not been well inventoried because of a lack of time and a visit during an inappropriate season.

In fact, from these data it seems plausible that the whole chain of hills running from the north to the south, is inhabited by rare or endemic species. It will definitely be worthwhile to return to those hills to collect additional botanical information.

Within the 11 families studied in detail, 29 endemic species (category 1A or 1B) were observed. Thus by extrapolation we may state that around 11% of the plant species of the Monts Doudou are endemic to the region. Considering the fact that the more common species have a higher chance of being collected than the rarer ones, we assume new inventory activities will add comparatively many rarer species to the species list. Therefore, we assume that the figure of 11% will increase in the future.

The Pleistocene forest refuge indicators. Sosef (1994) had noted the presence of seven species of *Begonia* (*B. clypeifolia, B. dewildei, B. hirsutula, B. lacunosa, B. mildbraedii, B. scutulum* and *B. vankerckhovenii*) occurring in the Monts Doudou Reserve, and which are recognized as indicators of a Pleistocene forest refuge. The presence of these seven species was a sufficiently strong indication to denote the Monts Doudou area as a former rain forest refuge.

During the present fieldwork, we have identified another two indicator species: *Begonia letouzeyi* and *Begonia scutifolia*. Another collection of *Begonia* may well represent an undescribed new species. (More material is needed, however, to exclude the possibility that the material originated from a hybrid population.) These new discoveries strengthen the hypothesis of the existence of a rain forest refuge at the Monts Doudou during the Pleistocene.

Plot inventory

Realization of the plots. In total, 18 plots have been established. All plots were situated in primary forest vegetation, seven in the low altitude zone, six in the medium altitude zone, and five in the high altitude zone. Table 5 shows the location and altitude of each plot.

All data concerning the plot inventory are presented in Appendix C. The majority of the reference samples of the subplot inventory (mostly sterile) have not yet been identified due to a lack of time and human capacity. Therefore, we only present results concerning the total number of different species in the subplots.

Comparative analyses of the plots. Table 6 shows the averaged results of the plots and subplots at the three altitudinal zones. The ANOVA showed significant differences among the plot means for number of tree families (P = 0.0129), number of tree species (P = 0.0112), and number of stems (P = 0.0132) at different altitude zones. The multiple comparison tests showed that for all three parameters only the differences between the low altitude plots and high altitude plots are significant. The plot means of the medium altitude plots are not significantly different from the low and high altitude plot means (α = 0.05). The number of tree species per family in the plots and the number of species in the subplots are not significantly different for the plots at different altitudes (P = 0.8334 and P = 0.1113, respectively).

Figure 5 depicts the results of the individual plots and subplots, showing an increasing gradient of the number of families, species, and stems in relation to altitude. The relation

TABLE 5. Location and altitude of each plot.

Plot	Latitude and longitude	Altitude (m)
1	2°17′S, 10°30′E	100
2	2°17′S, 10°30′E	100
3	2°14′S, 10°27′E	150
4	2°17.6′S, 10°30.3′E	150
5	2°13′S, 10°24′E	380
6	2°13′S, 10°24′E	460
7	2°14′S, 10°24′E	650
8	2°13′S, 10°24′E	350
9	2°27.6′S, 10°32′E	195
10	2°27.4′S, 10°32′E	535
11	2°27.4′S, 10°32.1′E	430
12	2°28′S, 10°32′E	145
13	2°27.6′S, 10°32.5′E	265
14	2°28.0′S, 10°32.5′E	150
15	2°23.1′S, 10°30.7′E	545
16	2°24.4′S, 10°27.1′E	655
17	2°22.5′S, 10°28.8′E	225
18	2°23.0′S, 10°29.5′E	230

between altitude and all variables was well explained by linear relationships. Tests showed that curvilinear relationships did not add much explanatory power (results not shown). The linear relationships indicate that the numbers of families and species increase with altitude, with the highest numbers at the highest altitudes (see also Table 6). These results do not confirm those obtained from the biodiversity analysis (Table 4), which indicated that the highest biodiversity values are found between 400 and 600 m, decreasing again between 600 and 700 m. The decreasing biodiversity at high altitudes shown in Table 4 is probably due to sampling error, as was already explained in the biodiversity analysis section. A more representative sampling will probably also show an increase of biodiversity at the highest altitudes, in accordance with the results of the plot inventory presented in Table 6 and Figure 5.

The correlations of altitude with number of tree families in the plots ($r = 0.58$), number of tree species in the plots ($r = 0.60$), number of stems in the plots ($r = 0.60$), and number of species in the subplots ($r = 0.54$) are significant at the 5% level ($P = 0.0115$, $P = 0.0085$, $P =$

TABLE 6. Means and standard errors of the means of numbers of families, species, and stems per altitudinal zone.

	Low altitude < 200 m	Medium altitude 200–450 m	High altitude > 450 m
Tree families (plot)	15.0 ± 1.35	16.2 ± 0.83	20.4 ± 0.93
Tree species (plot)	27.3 ± 2.59	31.8 ± 1.99	38.6 ± 1.66
Tree species/Family (plot)	1.866 ± 0.184	1.97 ± 0.080	1.89 ± 0.036
Stems (plot)	73.9 ± 7.99	92.0 ± 4.89	105.2 ± 4.49
All species (subplot)	64.4 ± 2.55	74.0 ± 12.39	89.2 ± 4.43

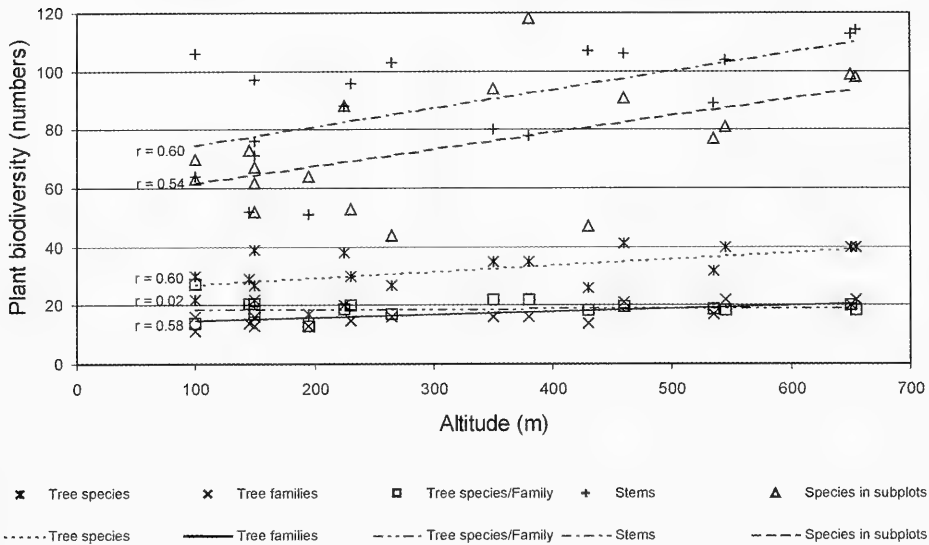## Influence of altitude on plant biodiversity

FIGURE 5. Correlations of plot altitude and numbers of tree families, tree species, tree species / family, stems, and species in the subplots.

0.0078, and P = 0.0215, respectively). The correlation of altitude with mean number of tree species per family is not significant (r = 0.02, P = 0.9383). This means that the number of tree species in the plots is significantly increasing with the altitude, but that the effect is caused by a significant increase in the number of tree families, while the number of tree species per family remains constant. Note that although the mean species number for the subplots (Table 6) is not significantly different between the altitude zones, the overall correlation of altitude and species number in the subplots is significant.

To study differences in species composition and/or dominance between the altitudinal zones, we calculated the total number of stems of the more common species for each zone. To eliminate the effect of local dominance, we only took species into account that were encountered in at least two different plots at a given altitudinal zone. Furthermore, we made an overview of the total number of tree species per family for every altitudinal zone. The results are shown in Figures 6 to 11, and discussed below.

Considering the diagrams giving the number of tree species per family (Figures 7, 9 and 11), we observe that two families (Caesalpiniaceae and Euphorbiaceae) are well represented in all three zones. Caesalpiniaceae is dominant in the canopy. The understory, however, is frequented by *Dichostemma glaucescens* (Euphorbiaceae), *Santiria trimera* (Burseraceae), various *Diospyros* (Ebenaceae) species, and Olacaceae such as *Diogoa zenkeri, Strombosia pustulata* and *Strombosiopsis tetrandra,* as can be derived from Figures 6, 8, and 10.

At low altitude, the canopy is dominated by Caesalpiniaceae and Mimosaceae, with species such as *Dialium angolense* and *Pentaclethra eetveldeana.* In the understory *Dichostemma glaucescens, Meiocarpidium lepidotum*, and a large variety of *Diospyros* species are frequently encountered.

FIGURE 6. Total number of stems for the most common tree species at low altitude (<200 m; cumulative data from plots 1, 2, 3, 4, 9, 12 and 14).

FIGURE 7. Number of tree species per family at low altitude (<200 m; cumulative data from plots 1, 2, 3, 4, 9, 12 and 14).

FIGURE 8. Total number of stems for the most common tree species at medium altitude (200–400 m; cumulative data from plots 5, 8, 11, 13, 17 and 18).

FIGURE 9. Number of tree species per family at medium altitude (200–450 m; cumulative data from plots 5, 8, 11, 13, 17 and 18).
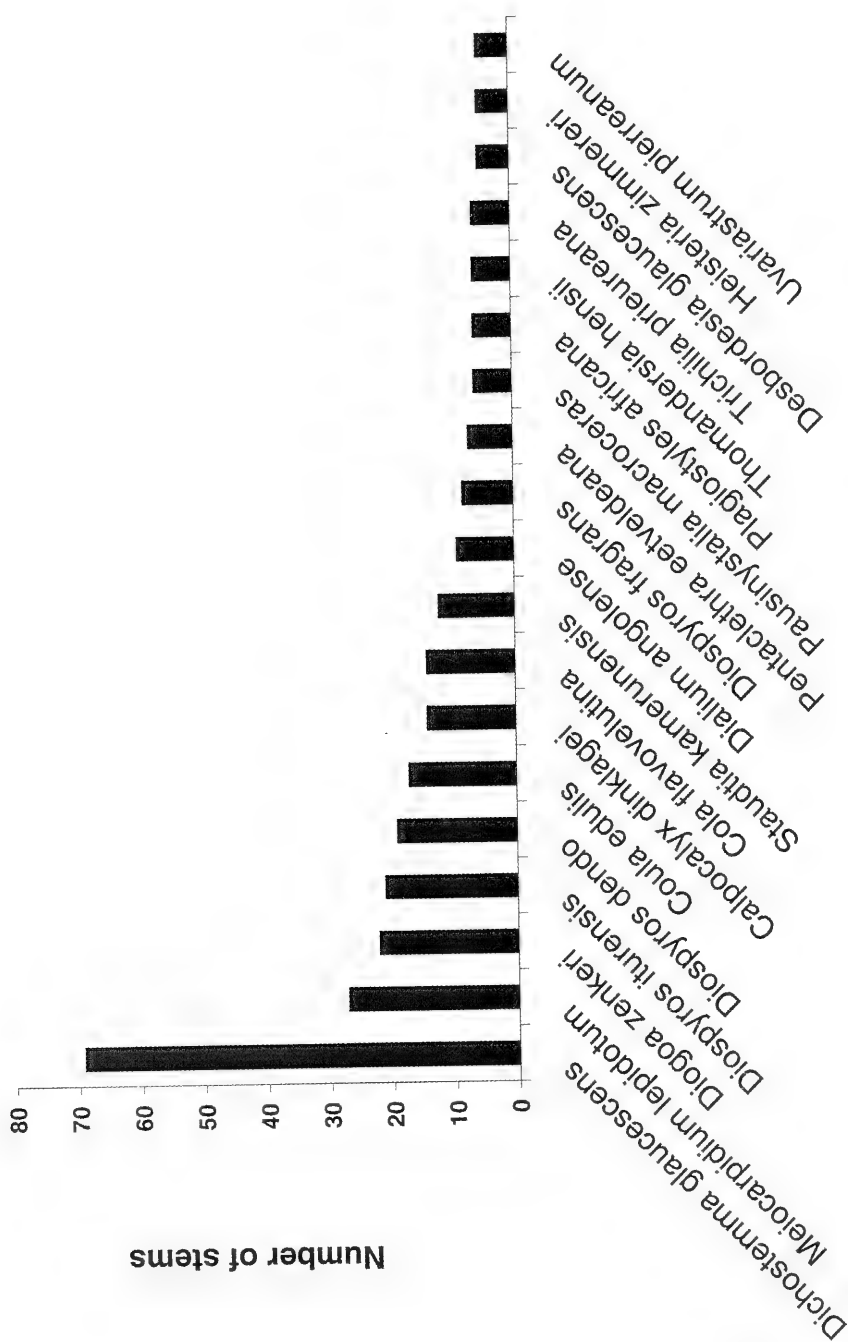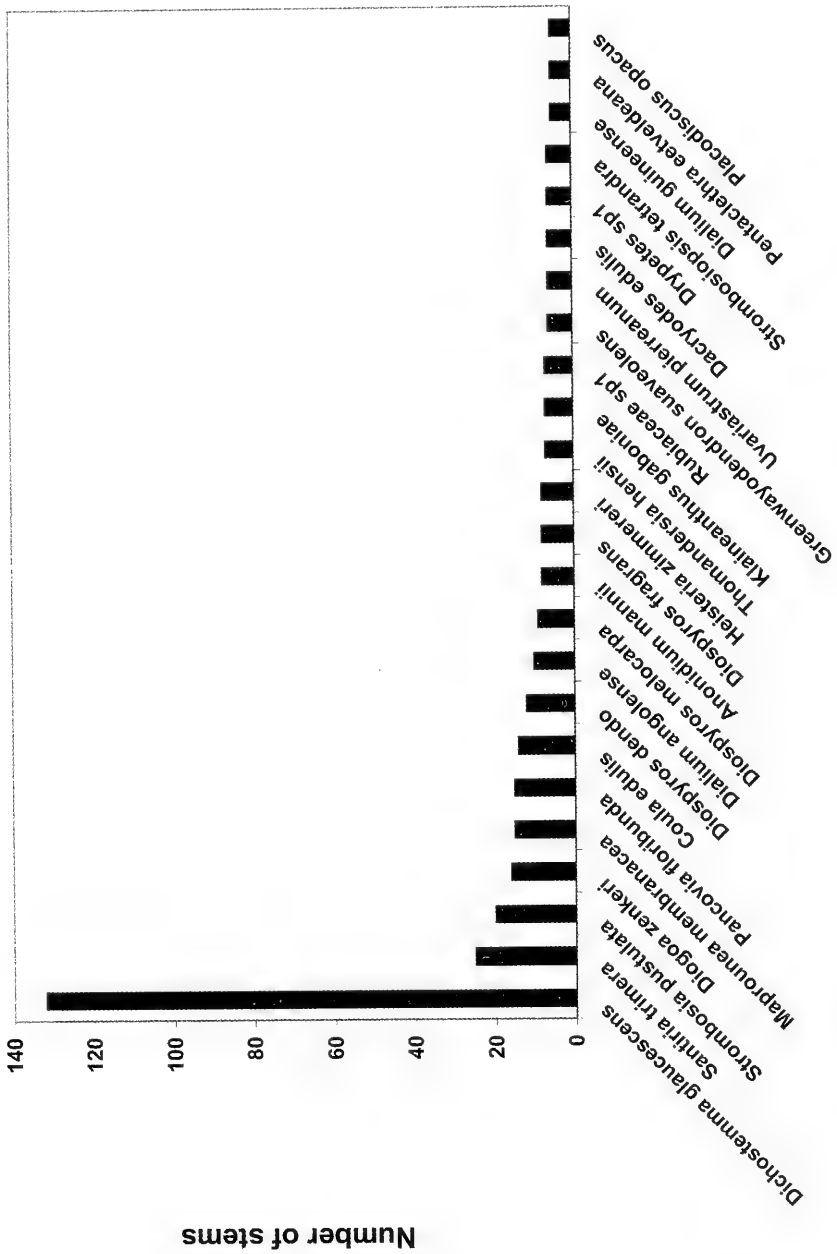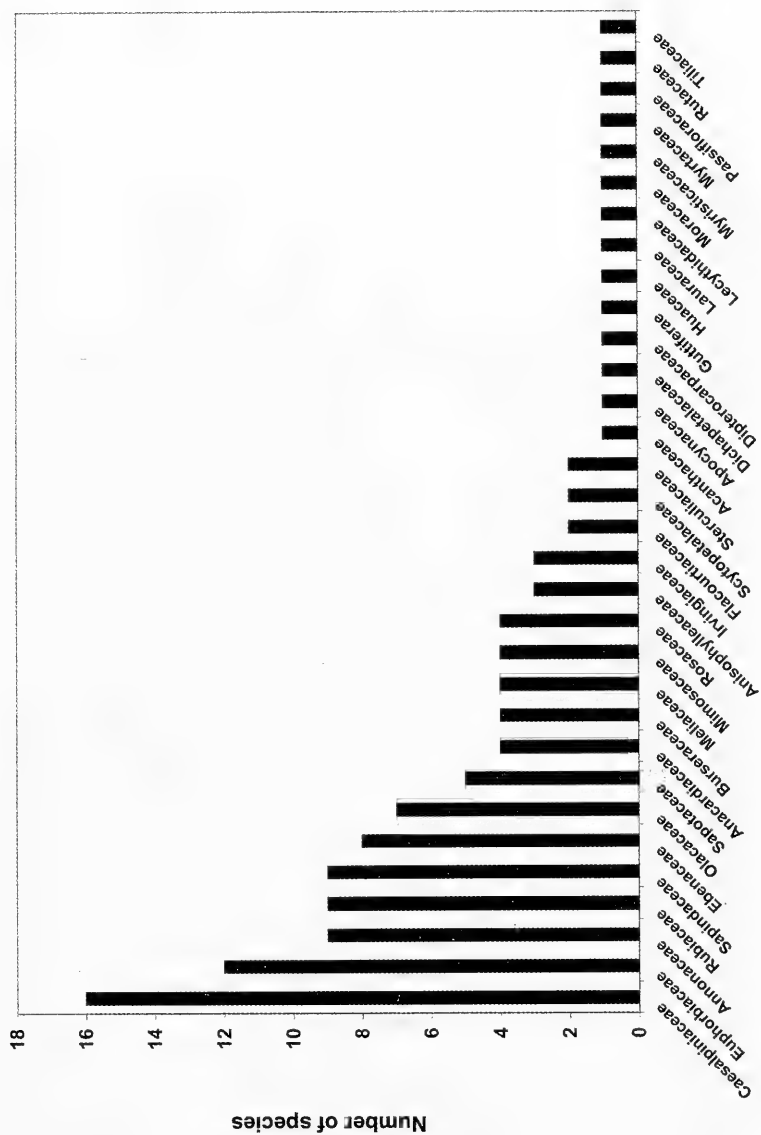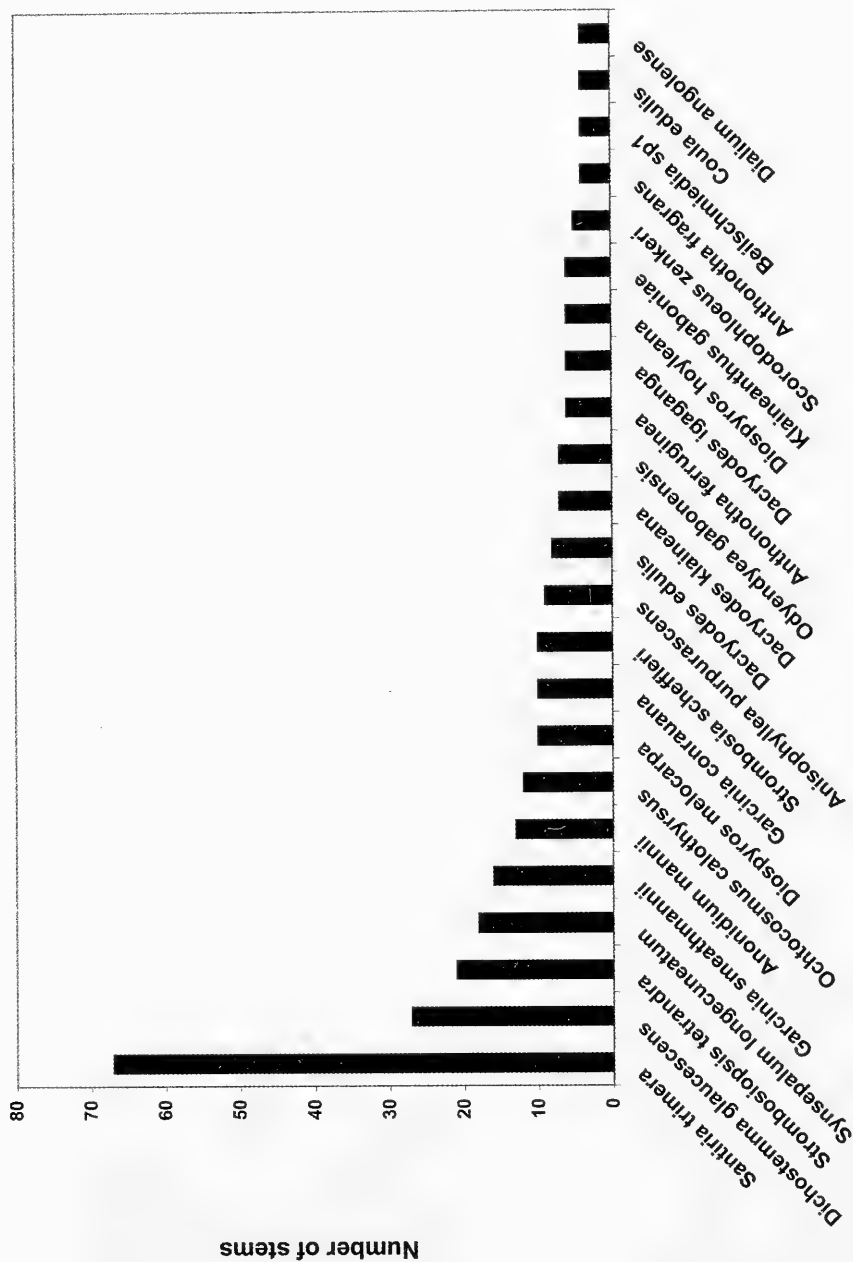
FIGURE 10. Total number of stems for the most common tree species at high altitude (>450 m; cumulative data from plots 6, 7, 10, 15 and 16).
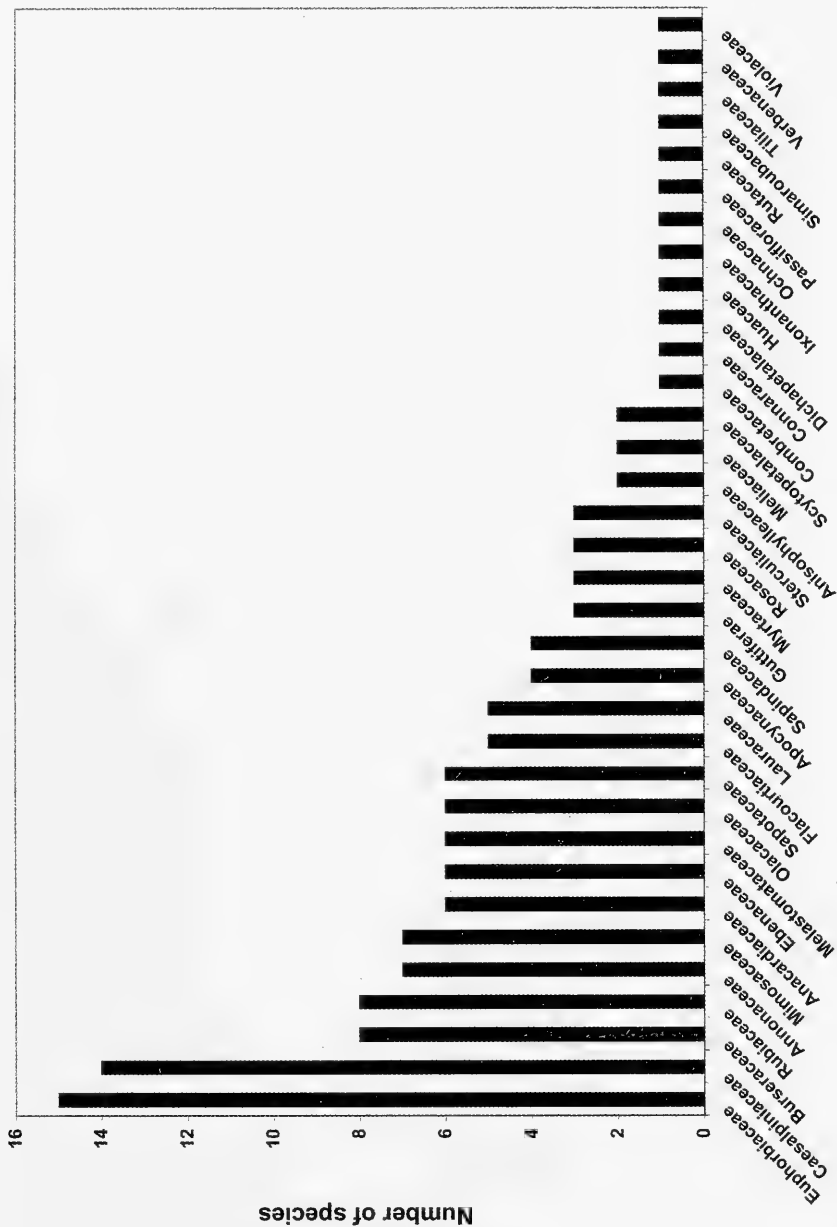
FIGURE 11. Number of tree species per family at high altitude (>450 m; cumulative data from plots 6, 7, 10, 15 and 16).

37

At medium altitude, we note an increase in the number of Annonaceae species. In the canopy layer *Librevillea klainei*, *Plagiosiphon emarginatus*, and *Dialium angolense* are frequently observed. *Dichostemma glaucescens*, *Santiria trimera*, and *Strombosia pustulata* are often present in the understory.

At high altitude, we note an increase in the number of Burseraceae, due to the presence of species such as *Aucoumea klaineana* and *Dacryodes igaganga*. The understory is dominated by *Santiria trimera*, *Dichostemma glaucescens*, and *Strombosiopsis tetrandra*. Species such as *Synsepalum longecuneatum* and *Ochthocosmus calothyrsus* are frequent and confined to this altitude.

DESCRIPTION OF THE VARIOUS VEGETATION TYPES

LOW ALTITUDE FOREST (<200 m)

Forest on dry soil. This forest is usually established on level ground. The understory is open. The canopy is fairly high, approximately 35–45 m. The following species are characteristic:

Large trees: *Desbordesia glaucescens*, *Pausinystalia macroceras*, *Scorodophloeus zenkeri*, *Pterocarpus soyauxii*, *Pentaclethra eetveldeana*, *Gambeya africana*, *Celtis tessmannii*, *Dialium angolense*, and *Cylicodiscus gabonensis*.

Medium-sized trees: *Coula edulis*, *Greenwayodendron suavolens*, *Picralima nitida*, *Staudtia kamerunensis*, *Diospyros hoyleana*, and especially the abundance of *Meiocarpidium lepidotum*.

Smaller trees: *Dichostemma glaucescens*, *Plagiostyles africana*, *Xylopia hypolampra*, *Diospyros dendo*, *Diospyros obliquifolia*, *Diospyros zenkeri*, and *Grewia coriacea*.

In the understory *Salacia* spp., *Leptonychia echinocarpa*, and *Rinorea* spp. are often encountered, and may be abundant in places.

Swamp forest. This forest occurs on badly drained soils. The understory is open, often with an abundance of lianas like *Landolphia mannii*. The canopy is high, about 40–45 m. This forest, which is often encountered along water courses, is characterized by the following species:

Tree layer: *Khaya ivorensis*, *Carapa procera*, *Gilbertiodendron dewevrei*, *Calpolcalyx dinklagei*, *Calpocalyx heitzii*, and *Hallea ciliata*.

Shrub layer: *Massularia acuminata*, *Sterculia tragacantha*, *Greenwayodendron suavolens*, *Trichilia pierreana*, *Homalium le-testui*, *Oncoba glauca*, *Hallea ciliata*, *Cynometra lujae*, *Cynometra nyangensis*, *Uvariastrum pierreanum*, *Anthonota macrophylla*, and *Ouratea elongatum*.

Gallery forest. In the southeastern region of the Monts Doudou Reserve, savannahs dominate the landscape, but the valleys in this region are generally occupied by a type of forest called gallery forest. This forest forms a refuge for big mammals (elephant, buffalo), large monkeys and other animals. Gallery forest is generally found along watercourses or small marshes. The forest is diverse and contains, amongst others: *Tetrapleura tetraptera*, *Ceiba pentandra*, *Dracaena* sp., *Anthocleista vogelii*, *Berlinia bracteosa*, *Daniellia klainei*, *Elaeophorbia drupifera*, *Landolphia mannii*, *Symphonia globulifera*, *Xylopia quintasii*, *Strychnos aculeata*, and *Lannea welwitschii*.

MEDIUM ALTITUDE FOREST (200–450 m)

This forest type, which rises from the hill slopes, has an understory characterized by, amongst others: *Dichostemma glaucescens*, *Lasianthera africana*, *Rinorea* spp., *Santiria trimera*, and *Strombosia pustulata.*

The tree layer is generally dominated by species such as *Parkia bicolor*, *Dacryodes igaganga*, *Entandrophragma angolense*, and *Librevillea klaineana.*

The shrub layer is rich in species; the most frequently encountered ones are *Trichoscyha abut*, *T. acuminata*, and *Cleistopholis glauca*. The forest comprises several characteristic lianas such as *Strychnos aculeata*, *Landolphia mannii*, and *Salacia* spp. The presence of the tree fern *Cyathea camerooniana* along several of the streams is also of note.

HIGH ALTITUDE FOREST (> 450 m)

These forests, occurring on the ridges and hill tops, are characterized by the frequent occurrence of *Santiria trimera*. Various *Begonia* species are common, especially on rock faces that occupy the high ridges.

The understory is generally open and consists mainly of shrubs such as *Phyllanthus diandrus*, *Scaphopetalum blackii*, *Santiria trimera*, *Anthonota fragrans*, *Isolona campanulata*, *Trichoscypha acuminata*, *Anonidium mannii*, *Dicranolepis disticha*, and *Maesobotrya pauciflora*.

The most important large tree species are *Aucoumea klaineana*, *Erythrophleum ivorense*, *Desbordesia glaucescens*, *Klainedoxa gabonensis*, *Syzygium staudtii*, and *Copaifera religiosia*.

SAVANNAH

The savannah vegetation type is mainly located southwest of Mourindi, on dry soil. It is dominated by grasses such as *Andropogon chinensis*, *Andropogon gayanus*, *Anadelphia afzeliana*, and *Hyparrhenia familiaris*. Some other frequently encountered grasses are *Panicum brazzavillense*, *Rottboellia cochinchinensis*, and *Elymandra gossweileri*. A few shrub species are to be found, such as *Annona senegalensis*, *Dichrostachys cinerea*, and *Sarcocephalus latifolius*. Regarding the other herbaceous species, the presence of *Asparagus* sp. is remarkable.

CONCLUSIONS

1. The Monts Doudou Reserve can now be considered as a botanically fairly well known area. The number of species recorded up to now is 991. The number of botanical collections has increased towards 2459, and around 400 other collections are awaiting their treatment and identification.

2. Around 11% of the plant species of the Monts Doudou Reserve have a very limited area of distribution, and are endemic to the region. This figure is likely to increase following renewed collecting activities.

3. The hypothesis that the Monts Doudou represent a former Pleistocene rain forest refuge area is confirmed and reinforced by observations of additional indicator species.

4. The areas having a very high botanical biodiversity, including high numbers of rare and endemic species, are situated at the medium (300 m) and high altitude (above 400 m) zones of the Monts Doudou Reserve.

5. The botanical biodiversity value of a given region should be studied in relation to the total number of species and the collecting index (number of specimens per square kilometer).

6. The diversity of the vegetation (number of species per surface unit) shows a clear relationship with, and increases considerably with, increasing altitude. This is true for both the woody and herbaceous flora.

RECOMMENDATIONS

A thorough botanical inventory of the Mont Moungoubi, and other high altitude zones, is strongly recommended. We foresee the discovery of many other, very rare species or even some new to science.

Further development of a standardized method to determine the botanical biodiversity value of a given region in Gabon is strongly recommended.

The availability of a detailed vegetation map will render an inventory of plots much more worthwhile, as more firm conclusions and recommendations related to conservation and management can be made. The development of such a map for the Monts Doudou Reserve is therefore highly recommended.

To facilitate future scientific research in the Monts Doudou one has to emphasize the improvement of the existing forest roads.

In order to understand the vegetation dynamics between the forest and the savannah, it is important to leave certain savannahs untouched by man for a certain period of time.

In order to get a better understanding of the forest dynamics of the Monts Doudou, it would be worthwhile to re-inventory the 1 ha plot established by J. M. Reitsma in 1985–1987 (Reitsma 1988).

Achoundong of the National Herbarium of Cameroon, for having identified many of the specimens.

The guides, porters, and cooks of Mourindi, notably Grace P. Doukaga, Dieudonné Ibinga, Kévin Koumba, Fabrice Mamboundou, Jean Mbina and Juldas Mbina.

And finally, all personnel of the Herbier National du Gabon, for their indispensable assistance during the fieldwork, sometimes performed in difficult circumstances, and for their help during the treatment and identification of the material.

APPENDIX A

SPECIES LIST OF THE MONTS DOUDOU RESERVE
(based on botanical collections and plot inventories)

DICOTYLEDONAE
ACANTHACEAE (27)
Adhatoda buchholzii (Lindau) S.Moore
Adhatoda le-testui (R.Benoist) Heine
Anisosepalum alboviolaceum (R.Benoist) E.Hossain ssp. *alboviolaceum*
Anisotes macrophyllus (Lindau) Heine
Asystasia gangetica (L.) T.Anderson
Brillantaisia soyauxii Lindau
Brillantaisia vogeliana (Nees) Benth.
Dicliptera verticillata (Forsk.) C.Christ.
Elytraria marginata Vahl
Hypoestes forskaolii (Vahl) R.Br.
Justicia bolomboensis De Wild.
Justicia claessensii De Wild.
Justicia laxa T.Anderson
Justicia tenella (Nees) T.Anderson
Nelsonia canescens (Lam.) Spreng.
Phaulopsis angolana S.Moore
Physacanthus batanganus (G.Braun & K.Schum.) Lindau
Physacanthus nematosiphon (Lindau) Rendle & Britten
Pseuderanthemum tunicatum (Afzel.) Milne-Redh.
Rhinacanthus virens (Nees) Milne-Redh.
Saintpauliopsis lebrunii Staner
Staurogyne letestuana R.Benoist
Stenandrium gabonicum (R.Benoist) Vollesen
Stenandrium guineense (Nees) K.Vollesen
Stenandrium talbotii (S.Moore) Vollesen
Thomandersia butayei De Wild.
Thomandersia hensii De Wild. & Th.Dur.

AMARANTHACEAE (3)
Achyranthes aspera Wall.
Celosia sp.
Cyathula prostrata (L.) Blume

41

ANACARDIACEAE (6)
Lannea welwitschii (Hiern) Engl.
Pseudospondias longifolia Engl.
Sorindeia nitidula Engl.
Spondias mombin L.
Trichoscypha acuminata Engl.
Trichoscypha gambana Jongkind

ANCISTROCLADACEAE (1)
Ancistrocladus sp.

ANISOPHYLLEACEAE (3)
Anisophyllea myriosticta J.J.Floret
Anisophyllea polyneura J.J.Floret
Anisophyllea purpurascens Hutch. & Dalz.

ANNONACEAE (32)
Annickia chlorantha (Oliv.) Setten & Maas
Annickia pilosa (Exell) Setten & Maas
Annona senegalensis Pers.
Anonidium mannii (Oliv.) Engl. & Diels
Cleistopholis glauca Pierre ex Engl. & Diels
Cleistopholis staudtii Engl. & Diels
Greenwayodendron suaveolens (Engl. & Diels) Verdc. ssp. *suaveolens*
Isolona campanulata Engl. & Diels
*Isolona hexaloba (*Pierre) Engl. & Diels
Isolona zenkeri Engl.
Letestudoxa bella Pellegr.
Meiocarpidium lepidotum (Oliv.) Engl. & Diels
Monanthotaxis sp.
Polyalthia suaveolens Engl. & Diels
Polyceratocarpus parviflorus (Baker f.) Ghesq.
Popowia sp.
Pseudartabotrys le-testui Pellegr.
Uvaria comperei Le Thomas
Uvaria hispidocostata Pierre ex Engl. & Diels
Uvaria klaineana Engl. & Diels
Uvaria lastoursvillensis Pellegr.
Uvaria psorosperma Engl. & Diels
Uvariastrum pierreanum Engl. & Diels
Uvariastrum pynaertii De Wild.
Uvariopsis congolana (De Wild.) Fries
Xylopia acutiflora (Dunal) A.Rich.
Xylopia aethiopica (Dunal) A.Rich.
Xylopia hypolampra Mildbr.
Xylopia phloiodora Mildbr.
Xylopia pynaertii De Wild.
Xylopia quintasii Engl. & Diels

Xylopia staudtii Engl. & Diels

APOCYNACEAE (29)
Callichilia bequaertii De Wild.
Calocrater preussii K.Schum.
Cyclocotyla congolensis Stapf
Cylindropsis parvifolia Pierre
Dictyophleba ochracea (K.Schum. ex Hallier f.) Pichon
Holarrhena floribunda (G.Don) Dur. & Schinz
Hunteria umbellata (K.Schum.) Hallier f.
Landolphia congolensis (Stapf) Pichon
Landolphia dewevrei Stapf
Landolphia foretiana (Pierre ex Jum.) Pichon
Landolphia glabra (Pierre ex Stapf) Pichon
Landolphia incerta (K.Schum.) Persoon
Landolphia mannii Dyer
Landolphia owariensis P.Beauv.
Landolphia pyramidata (Pierre) Persoon
Landolphia reticulata Hallier f.
Landolphia robustior (K.Schum.) Persoon
Orthopichonia cirrhosa (Radlk.) H.Huber
Picralima nitida (Stapf) Th. & H.Dur.
Pleiocarpa rostrata Benth.
Rauvolfia letouzeyi Leeuwenb.
Rauvolfia mannii Stapf
Rauvolfia vomitoria Afzel.
Tabernaemontana bouquetii (Boiteau) Leeuwenb.
Tabernaemontana crassa Benth.
Tabernaemontana letestui (Pellegr.) Pichon
Tabernanthe iboga Baill.
Voacanga bracteata Stapf
Voacanga psilocalyx Pierre ex Stapf

ARALIACEAE (1)
Schefflera barteri (Seem.) Harms

ARISTOLOCHIACEAE (2)
Pararistolochia ceropegioides (S.Moore) Hutch. & Dalziel
Pararistolochia triactina (Hook.f.) Hutch. & Dalziel

BALANOPHORACEAE (1)
Thonningia sanguinea Vahl

BALSAMINACEAE (6)
Impatiens floretii N.Hallé & A.M.Louis
Impatiens gossweileri G.M.Schulze ssp. *gossweileri*
Impatiens hians Hook.f.
Impatiens mackeyana Hook.f.

Impatiens niamniamensis Gilg
Impatiens palpebrata Hook.f.

BEGONIACEAE (24)
Begonia auriculata Hook.f.
Begonia capillipes Gilg
Begonia clypeifolia Hook.f.
Begonia dewildei Sosef
Begonia eboloensis Engl.
Begonia elaeagnifolia Hook.f.
Begonia elatostemmoides Hook.f.
Begonia fusialata Warb. var. *fusialata*
Begonia gabonensis J.J.de Wilde
Begonia hirsutula Hook.f.
Begonia komoensis Irmsch.
Begonia lacunosa Warb.
Begonia letouzeyi Sosef
Begonia longipetiolata Gilg
Begonia loranthoides Hook.f. ssp. *rhopalocarpa* (Warb.) J.J.de Wilde
Begonia macrocarpa Warb.
Begonia mannii Hook.f.
Begonia mildbraedii Gilg
Begonia poculifera Hook.f.
Begonia polygonoides Hook.f.
Begonia sciaphila Gilg ex Engl.
Begonia scutifolia Hook.f.
Begonia scutulum Hook.f.
Begonia vankerckhovenii De Wild.

BIGNONIACEAE (3)
Kigelia africana (Lam.) Benth.
Markhamia tomentosa (Benth.) K.Schum. ex Engl.
Newbouldia laevis (P.Beauv.) Seeman ex Bureau

BIXACEAE (1)
Bixa orellana L.

BOMBACACEAE (1)
Ceiba pentandra (L.) Gaertn.

BORAGINACEAE (1)
Heliotropium ovalifolium Forssk.

BURSERACEAE (10)
Aucoumea klaineana Pierre
Canarium schweinfurthii Engl.
Dacryodes buettneri (Engl.) H.J.Lam
Dacryodes edulis (G.Don) H.J.Lam

Dacryodes igaganga Aubrév. & Pellegr.
Dacryodes klaineana (Pierre) H.J.Lam
Dacryodes letestui (Pellegr.) H.J.Lam
Dacryodes macrophylla (Oliv.) H.J.Lam
Dacryodes normandii Aubrév. & Pellegr.
Santiria trimera (Oliv.) Aubrév. & Pellegr.

CACTACEAE (1)
Rhipsalis baccifera (J.S.Mill.) Stearn

CAESALPINIACEAE (56)
Anthonotha acuminata (De Wild.) J.Léonard
Anthonotha ferruginea (Harms) J.Léonard
Anthonotha fragrans (Baker f.) Exell & Hillcoat
Anthonotha macrophylla P.Beauv.
Anthonotha pynaertii (De Wild.) Exell & Hillcoat
Anthonotha trunciflora (Harms) J.Léonard
Aphanocalyx heitzii (Pellegr.) Wieringa
Aphanocalyx microphyllus (Harms) Wieringa ssp. *microphyllus*
Baikiaea insignis Benth.
Berlinia auriculata Benth.
Berlinia bracteosa Benth.
Berlinia confusa Hoyle
Bikinia coriacea (J.Morel ex Aubrév.) Wieringa
Bikinia letestui (Pellegr.) Wieringa
Bobgunnia fistuloides (Harms) Kirkbr. & Wiersema
Brachystegia mildbraedii Harms
Cassia chamaecrista L.
Cassia hirsuta L.
Cassia mannii Oliv.
Chamaecrista absus (L.) Irwin & Barneby
Copaifera religiosa J.Léonard
Crudia harmsiana De Wild. var. *velutina* J.Léonard
Cynometra lujae De Wild.
Cynometra mannii Oliv.
Cynometra nyangensis Pellegr.
Daniellia klainei Pierre ex A.Chev.
Daniellia soyauxii (Harms) Rolfe
Dialium angolense Welw. ex Oliv.
Dialium dinklagei Harms
Dialium guineense Willd.
Didelotia africana Baill.
Didelotia brevipaniculata J.Léonard
Distemonanthus benthamianus Baill.
Gilbertiodendron brachystegioides (Harms) J.Léonard
Gilbertiodendron ogoouense (Pellegr.) J.Léonard
Gilbertiodendron stipulaceum (Benth.) J.Léonard
Gilbertiodendron unijugum (Harms) J.Léonard

Griffonia physocarpa Baill.
Guibourtia ehie (A.Chev.) J.Léonard
Guibourtia tessmannii (Harms) J.Léonard
Hylodendron gabunense Taub.
Hymenostegia floribunda (Benth.) Harms
Hymenostegia klainei Pierre ex Pellegr.
Hymenostegia ngounyensis Pellegr.
Isomacrolobium conchyliophorum (Pellegr.) Aubrév. & Pellegr.
Julbernardia brieyi (De Wild.) Troupin
Librevillea klainei (Pierre ex Harms) Hoyle
Neochevalierodendron stephanii (A.Chev.) J.Léonard
Oddoniodendron micranthum (Harms) Baker
Plagiosiphon emarginatus (Hutch. & Dalz.) J.Léonard
Scorodophloeus zenkeri Harms
Senna alata (L.) Roxburgh.
Senna timoriensis (DC.) Irwin & Barneby
Tetraberlinia bifoliolata (Harms) Hauman
Tetraberlinia polyphylla (Harms) J.Léonard

CAMPANULACEAE (2)
Lobelia minutula Engl.
Wahlenbergia sp.

CELASTRACEAE (incl. HIPPOCRATEACEAE) (20)
Apodostigma pallens (Planch. ex Oliv.) Wilcz. var. *buchholzii* (Loes.) N.Hallé
Elachyptera holtzii (Loes. ex Harms) Wilcz. ex N.Hallé
Hippocratea myriantha Oliv.
Loeseneriella apocynoides (Welw. ex Oliv.) N.Hallé ex J.Raynal
Prionostemma fimbriata (Exell) N.Hallé
Salacia debilis (G.Don) Walp.
Salacia dimidia N.Hallé
Salacia elegans Welw. ex Oliv.
Salacia erecta (G.Don) Walp.
Salacia hispida Blakelock
Salacia lehmbachii Loes.
Salacia letestui Pellegr.
Salacia loloensis Loes.
Salacia mayumbensis Exell & Mendonça
Salacia nitida (Benth.) N.E.Br.
Salacia pyriformis (Sabine) Steud.
Salacia regeliana J.Braun & K.Schum.
Salacia staudtiana var. *tsopoensis* (De Wild.) N.Hallé
Salacia talbotii Baker f.
Salacia whytei Loes.

CERATOPHYLLACEAE (1)
Ceratophyllum sp.

COMBRETACEAE (7)
Combretum aphanopetalum Engl. & Diels
Combretum bracteatum (Laws.) Engl. & Diels
Combretum falcatum (Welw. ex Hiern) Jongk.
Combretum mannii Engl. & Diels
Combretum paniculatum Vent.
Combretum rabiense Jongkind
Combretum racemosum P.Beauv.
Strephonema sericeum Hook.f.

COMPOSITAE (7)
Ageratum conyzoides L.
Aspilia africana (Pers.) C.D.Adams
Hypericophyllum congoense (O.Hoffm.) N.E.Br.
Mikania cordata (Burm.f.) Robinson
Struchium sparganophora (L.) Kuntze
Tithonia diversifolia (Hemsley) A.Gray
Vernonia stellulifera (Benth.) Jeffrey

CONNARACEAE (17)
Agelaea paradoxa Gilg
Agelaea pentagyna (Lam.) Baill.
Agelaea poggeana Gilg
Cnestis corniculata Lam.
Cnestis ferruginea Vahl ex DC.
Connarus longistipitatus Gilg
Hemandradenia mannii Stapf
Jollydora duparquetiana (Baill.) Pierre
Manotes expansa Sol. ex Planch.
Manotes griffoniana Baill.
Manotes macrantha (Gilg) Schellenb.
Rourea minor (Gaertn.) Alston
Rourea myriantha Baill.
Rourea obliquifoliolata Gilg
Rourea parviflora Gilg
Rourea solanderi Baker
Rourea thomsonii (Baker) Jongkind

CONVOLVULACEAE (1)
Ipomoea sp.

CRUCIFERAE (1)
Rorippa madagascariensis (DC.) Hara

CUCURBITACEAE (1)
Momordica sp.

DICHAPETALACEAE (18)
Dichapetalum choristilum Engl. var. *choristilum*
Dichapetalum congoense Engl. & Ruhl.
Dichapetalum dewevrei De Wild. & Th.Dur. var. *dewevrei*
Dichapetalum fructuosum Hiern
Dichapetalum gabonense Engl.
Dichapetalum glomeratum Engl.
Dichapetalum heudelotii (Planch. ex Oliv.) Baill. var. *heudelotii*
Dichapetalum heudelotii (Planch. ex Oliv.) Baill. var. *hispidum* (Oliv.) Breteler
Dichapetalum insigne Engl.
Dichapetalum integripetalum Engl.
Dichapetalum lujae De Wild. & Th.Dur.
Dichapetalum madagascariense Poir. var. *madagascariense*
Dichapetalum melanocladum Breteler
Dichapetalum minutiflorum Engl. & Ruhl.
Dichapetalum parvifolium Engl.
Dichapetalum zenkeri Engl.
Dichapetalum spec. nov.
Tapura letestui Pellegr.

DILLENIACEAE (1)
Tetracera alnifolia Willd. ssp. *alnifolia*

DIPTEROCARPACEAE (1)
Marquesia excelsa (Pierre) R.E.Fr.

EBENACEAE (17)
Diospyros bipindensis Gürke
Diospyros canaliculata De Wild.
Diospyros cinnabarina (Gürke) F.White
Diospyros conocarpa Gürke & K.Schum.
Diospyros dendo Welw. ex Hiern
Diospyros fragrans Gürke
Diospyros gabunensis Gürke
Diospyros hoyleana F.White
Diospyros iturensis (Gürke) Letouzey & F.White
Diospyros mannii Hiern
Diospyros melocarpa F.White
Diospyros obliquifolia (Hiern ex Gürke) F.White
Diospyros physocalycina Gürke
Diospyros piscatoria Gürke
Diospyros suaveolens Gürke
Diospyros zenkeri (Gürke) F.White

EUPHORBIACEAE (47)
Alchornea cordifolia (Schum. & Thonn.) Müll.Arg.
Alchornea floribunda Müll.Arg.
Bridelia atroviridis Müll.Arg.

Bridelia ferruginea Benth.
Bridelia micrantha (Hochst.) Baill.
Centroplacus glaucinus Pierre
Cleistanthus polystachyus Hook.f. ex Planch.
Croton mubango Müll.Arg.
Croton sylvaticus Hochst. ex Krauss
Crotonogyne manniana Müll.Arg.
Cyathogyne viridis Müll.Arg.
Cyrtogonone argentea (Pax) Prain
Dichostemma glaucescens Pierre
Discoglypremna caloneura (Pax) Prain
Drypetes capillipes (Pax) Pax & K.Hoffm.
Drypetes gilgiana (Pax) Pax & K.Hoffm.
Drypetes ituriensis Pax & K.Hoffm.
Drypetes molunduana Pax & K.Hoffm.
Drypetes pierreana Hutch.
Elaeophorbia drupifera (Thonn.) Stapf
Klaineanthus gaboniae Pierre ex Prain
Macaranga barteri Müll.Arg.
Macaranga gabunica Prain
Macaranga poggei Pax
Maesobotrya barteri (Baill.) Hutch. var. *barteri*
Maesobotrya pauciflora Pax
Mallotus oppositifolius (Geisel.) Müll.Arg.
Maprounea membranacea Pax & K.Hoffm.
Mareya micrantha (Benth.) Müll.Arg.
Mareyopsis longifolia (Pax) Pax & K.Hoffm.
Margaritaria discoideus (Baill.) Webster
Microdesmis sp.
Mildbraedia paniculata Pax
Phyllanthus diandrus Pax
Phyllanthus discoideus Pax
Phyllanthus muelleranus (O.Kuntze) Exell
Plagiostyles africana (Müll.Arg.) Prain
Pogonophora letouzeyi Feuillet
Protomegabaria sp.
Pycnocoma angustifolia Prain
Sapium guineense (Benth.) Kuntze
Sibangea arborescens Oliv.
Thecacoris leptobotrya (Müll.Arg.) Brenan
Tragia sp.
Uapaca acuminata (Hutch.) Pax & K.Hoffm.
Uapaca guineensis Müll.Arg.
Uapaca heudelotii Baill.

FLACOURTIACEAE (9)
Casearia barteri Mast.
Dovyalis zenkeri Gilg

Homalium letestui Pellegr.
Oncoba brachyanthera Oliv.
Oncoba dentata Oliv.
Oncoba flagelliflora (Mildbr.) Hul
Oncoba glauca (P.Beauv.) Planch.
Scottellia klaineana Pierre
Trichostephanus gabonensis Breteler

GENTIANACEAE (1)
Voyria primuloides Baker

GESNERIACEAE (2)
Acanthonema sp.
Epithema tenue C.B.Clarke

GUTTIFERAE (13)
Allanblackia floribunda Oliv.
Endodesmia calophylloides Benth.
Garcinia conrauana Engl.
Garcinia kola Heckel
Garcinia lucida Vesque
Garcinia ovalifolia Oliv.
Garcinia punctata Oliv.
Garcinia smeathmannii (Planch. & Triana) Oliv.
Garcinia volkensii Baker
Harungana madagascariensis Lam. ex Poir.
Pentadesma butyracea Sabine
Psorospermum tenuifolium Hook.f.
Vismia rubescens Oliv.

HUACEAE (3)
Afrostyrax kamerunensis Perkins & Gilg
Afrostyrax lepidophyllus Mildbr.
Hua gabonii Pierre ex De Wild.

ICACINACEAE (9)
Desmostachys brevipes (Engl.) Sleumer
Desmostachys oblongifolia (Engl.) Villiers
Desmostachys tenuifolius Oliv. var. *tenuifolius*
Icacina claessensii De Wild.
Icacina mannii Oliv. var. *lebrunii* Boutique
Icacina mannii Oliv. var. *mannii*
Lasianthera africana P.Beauv.
Leptaulus daphnoides Benth.
Pyrenacantha acuminata Engl.
Rhaphiostylis ferruginea Engl. var. *ferruginea*

IRVINGIACEAE (4)
Desbordesia glaucescens (Engl.) Tiegh.
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.
Klainedoxa gabonensis Pierre ex Engl. var. *gabonensis*
Klainedoxa trillesii Pierre ex v.Tiegh.

IXONANTHACEAE (1)
Ochtocosmus calothyrsus (Mildbr.) Hutch. & Dalz.

LABIATAE (7)
Achyrospermum ciliatum Gürke
Achyrospermum oblongifolium Baker
Hyptis lanceolata Poir.
Ocimum sp.
Platostoma africanum P.Beauv.
Solenostemon monostachyus (P.Beauv.) Briq.
Solenostemon repens (Gürke) J.K.Morton

LAURACEAE (2)
Beilschmiedia dinklagei (Engl.) Robyns & Wilczek
Beilschmiedia mannioides Robyns & Wilczek

LECYTHIDACEAE (2)
Napoleonaea sp.
Petersianthus macrocarpus (P.Beauv.) Liben

LEPIDOBOTRYACEAE (1)
Lepidobotrys staudtii Engl.

LINACEAE (5)
Hugonia micans Engl.
Hugonia planchonii Hook.f. var. *planchonii*
Hugonia platysepala Welw. ex Oliv.
Hugonia villosa Engl.
Pinacopodium congolense (S.Moore) Exell & Mendonça

LOGANIACEAE (12)
Anthocleista schweinfurthii Gilg
Anthocleista vogelii Planch.
Mostuea batesii Baker
Mostuea brunonis Didr. var. *brunonis*
Strychnos aculeata Solered.
Strychnos canthioides Leeuwenb.
Strychnos dale De Wild.
Strychnos ndengensis Pellegr.
Strychnos penninervis A.Chev.
Strychnos phaeotricha Gilg
Strychnos tricalysioides Hutch. & M.B.Moss

Strychnos urceolata Leeuwenb.

LORANTHACEAE (4)
Globimetula cornutibracteata Bulle ex Wiens & Polhill
Globimetula dinklagei (Engl.) Tiegh.
Loranthus sp.
Phragmanthera batangae (Engl.) S.Balle

MALPIGHIACEAE (3)
Acridocarpus longifolius (G.Don) Hook.f.
Acridocarpus macrocalyx Engl.
Acridocarpus smeathmannii (DC.) Guill. & Perr.

MALVACEAE (8)
Hibiscus diversifolius Jacq.
Hibiscus physaloides Guill. & Perr.
Hibiscus rostellatus Guill. & Perr.
Hibiscus surattensis L.
Sida linifolia Juss. ex Cav.
Sida rhombifolia L.
Sida stipulata Cav.
Urena lobata L.

MEDUSANDRACEAE (1)
Soyauxia floribunda Hutch.

MELASTOMATACEAE (28)
Amphiblemma ciliatum Cogn.
Amphiblemma molle Hook.f.
Amphiblemma setosum Hook.f.
Calvoa hirsuta Hook.f.
Calvoa orientalis Taub.
Calvoa pulcherrima Gilg ex Engl.
Calvoa seretii De Wild.
Cincinnobotrys acaulis (Cogn.) Gilg
Dicellandra barteri Hook.f. var. *barteri*
Dicellandra descoingsii Jacq.-Fél.
Dinophora spenneroides Benth.
Dissotis brazzae Cogn.
Dissotis congolensis (Cogn. ex Buettn.) Jacq.-Fél.
Dissotis multiflora (Sm.) Triana
Heterotis decumbens (P.Beauv.) Jacq.-Fél.
Medinilla mannii Hook.f.
Medinilla mirabilis (Gilg) Jacq.-Fél.
Memecylon calophyllum Gilg
Memecylon collinum Jacq.-Fél.
Memecylon klaineanum Jacq.-Fél.
Memecylon lateriflorum (G.Don) Bremek.

Memecylon salicifolium Jacq.-Fél.
Preussiella kamerunensis Gilg
Tristemma oreophilum Gilg
Tristemma vestitum Jacq.-Fél.
Warneckea cauliflora Jacq.-Fél.
Warneckea floribunda Jacq.-Fél.
Warneckea membranifolia (Hook.f.) Jacq.-Fél.
Warneckea sapinii (De Wild.) Jacq.-Fél.

MELIACEAE (9)
Carapa procera DC.
Entandrophragma angolense Welw. ex C.DC.
Entandrophragma congolense (De Wild.) A.Chev.
Guarea glomerulata Harms
Guarea thompsonii Sprague & Hutch.
Heckeldora staudtii (Harms) Staner
Khaya ivorensis A.Chev.
Trichilia monadelpha (Thonn.) J.J.de Wilde
Trichilia prieureana A.Juss.

MELIANTHACEAE (1)
Bersama maxima Baker

MENISPERMACEAE (3)
Cissampelos mucronata A.Rich.
Dioscoreophyllum cumminsii (Stapf) Diels
Jateorhiza macrantha (Hook.f.) Exell & Mendonça

MIMOSACEAE (19)
Acacia auriculiformis A.Cunn. ex Benth.
Aubrevillea platycarpa Pellegr.
Calpocalyx brevifolius Villiers
Calpocalyx dinklagei Harms
Calpocalyx heitzii Pellegr.
Cylicodiscus gabonensis Harms
Dichrostachys cinerea (L.) Wight & Arn. var. *platycarpa*
Entada gigas (L.) Fawcett & Rendle
Fillaeopsis discophora Harms
Mimosa pigra L.
Newtonia griffoniana (Baill.) Bak.f.
Newtonia leucocarpa (Harms) Gilbert & Boutique
Parkia bicolor A.Chev.
Parkia filicoidea Welw. ex Oliv.
Pentaclethra eetveldeana De Wild. & Th.Dur.
Pentaclethra macrophylla Benth.
Piptadeniastrum africanum (Hook.f.) Brenan
Pseudoprosopis gilletii (De Wild.) Villiers
Tetrapleura tetraptera (Schum. & Thonn.) Taub.

MORACEAE (7)
Dorstenia picta Bur.
Ficus conraui Warb.
Ficus subsagittifolia C.C.Berg
Ficus vogeliana (Miq.) Miq.
Myrianthus arboreus P.Beauv.
Myrianthus serratus (Trécul) Benth. & Hook. var. *letestui* De Ruiter
Trilepisium madagascariense Thouars ex DC.

MYRISTICACEAE (3)
Pycnanthus angolensis (Welw.) Warb.
Staudtia kamerunensis Warb. var. *gabonensis* (Warb.) Fouilloy
Staudtia kamerunensis Warb. var. *kamerunensis*

MYRSINACEAE (4)
Ardisia buesgenii (Gilg & Schellenb.) Taton
Ardisia lethomasiae Taton
Ardisia mayumbensis (R.Good) Taton
Ardisia staudtii Gilg

MYRTACEAE (4)
Eugenia klaineana (Pierre) Engl.
Eugenia obanensis Baker f.
Psidium guineense Sw.
Syzygium staudtii (Engl.) Mildbr.

NECTAROPETACEAE (1)
Pinacopodium congolense (S.Moore) Exell & Mendonça

NYMPHAEACEAE (1)
Nymphaea maculata Schum. & Thonn.

OCHNACEAE (13)
Campylospermum claessensii (De Wild.) Farron
Campylospermum excavatum (Tiegh.) Farron
Lophira alata Banks ex Gaertn.
Ouratea congesta (Oliv.) Engl. ex Gilg
Ouratea duparquetiana (Baill.) Gilg
Ouratea elongata (Oliv.) Engl.
Ouratea flava (Schum.) Hutch. & Dalziel
Ouratea gentilii De Wild.
Ouratea macrobotrys Gilg
Ouratea reticulata (P.Beauv.) Engl.
Ouratea turnerae (Hook.f.) Hutch. & Dalziel
Rhabdophyllum letestui Farron
Sauvagesia erecta L.

OLACACEAE (13)
Aptandra zenkeri Engl.
Coula edulis Baill.
Diogoa zenkeri (Engl.) Exell & Mendonça
Heisteria trillesiana Pierre
Heisteria zimmereri Engl.
Olax mannii Oliv.
Olax staudtii Engl.
Olax subscorpioidea Oliv. var. *subscorpioidea*
Strombosia grandifolia Hook.f. ex Benth.
Strombosia pustulata Oliv.
Strombosia scheffleri Engl.
Strombosiopsis tetrandra Engl.
Ximenia americana L.

OLEACEAE (1)
Chionanthus mannii (Sol.) Stearn ssp. *congestus* (Baker) Stearn

ONAGRACEAE (1)
Ludwigia sp.

OXALIDACEAE (1)
Biophytum talbotii (Baker f.) Hutch. & Dalziel

PAPILIONACEAE (34)
Abrus canescens Welw. ex Baker
Abrus fruticulosus Wall. ex W. & A.
Aganope gabonica (Baill.) Polhill
Angylocalyx talbotii Baker f. ex Hutch. & Dalz.
Angylocalyx zenkeri Harms
Baphia leptostemma Baill.
Baphia pilosa Baill.
Camoensia brevicalyx Benth.
Crotalaria goreensis Guill. & Perr.
Crotalaria ochroleuca G.Don
Dalbergia oblongifolia G.Don
Dalhousiea africana S.Moore
Desmodium adscendens (Sw.) DC. var. *adscendens*
Desmodium velutinum (Willd.) DC.
Dioclea reflexa Hook.f.
Eriosema glomeratum (Guill. & Perr.) Hook.f.
Eriosema parviflorum E.Mey. ssp. *parviflorum*
Eriosema psoraleoides (Lam.) G.Don
Indigofera capitata Kotschy
Indigofera hirsuta L. var. *hirsuta*
Leptoderris fasciculata (Benth.) Dunn
Millettia hypolampra Harms
Millettia marangensis Pellegr.

Millettia thonningii (Schum. & Thonn.) Bak.
Mucuna pruriens (L.) DC.
Platysepalum violaceum Welw. ex Baker
Pterocarpus soyauxii Taub.
Pueraria sp.
Stylosanthes sp.
Tephrosia nana Schweinf.
Uraria picta (Jacq.) DC.
Vigna gracilis (Guill. & Perr.) Hook.f.
Vigna reticulata Hook.f.
Zornia latifolia Sm.

PASSIFLORACEAE (6)
Barteria fistulosa Mast.
Barteria nigritana Hook.f.
Efulensia clematoides C.H.Wright
Paropsiopsis sp.
Passiflora edulis Sims
Passiflora foetida L.

PIPERACEAE (4)
Peperomia pellucida (L.) H.B.K.
Peperomia rotundifolia (L.) H.B.K.
Piper guineense Schum. & Thonn.
Piper umbellatum L.

POLYGALACEAE (2)
Carpolobia gossweileri (Exell) Petit
Polygala sp.

POLYGONACEAE (1)
Afrobrunnichia erecta (Asch.) Hutch. & Dalziel

RHAMNACEAE (1)
Maesopsis eminii Engl.

RHIZOPHORACEAE (1)
Cassipourea pumila Floret

ROSACEAE (6)
Dactyladenia barteri (Hook.f. ex Oliv.) Prance & F.White
Dactyladenia bellayana (Baill.) Prance & F.White
Dactyladenia pallescens (Baill.) Prance & F.White
Magnistipula cupheiflora Mildbr.
Maranthes chrysophylla (Oliv.) Prance
Maranthes glabra (Oliv.) Prance

RUBIACEAE (71)
Aidia micrantha (K.Schum.) F.White
Aoranthe cladantha (K.Schum.) Somers
Atractogyne gabonii Pierre
Aulacocalyx jasminiflora Hook.f. ssp. *jasminiflora*
Belonophora coriacea Hoyle
Bertiera aequatorialis N.Hallé
Bertiera aethiopica Hiern
Bertiera racemosa (G.Don) K.Schum.
Canthium crassum Schweinf.
Chassalia sp.
Chazaliella sp.
Coffea mayombensis A.Chev.
Commitheca letestuana N.Hallé
Corynanthe mayumbensis (R.D.Good) Raym.-Hamet
Corynanthe pachyceras K.Schum.
Craterispermum caudatum Hutch.
Craterispermum cerinanthum Hiern
Craterispermum laurinum Benth.
Craterispermum ledermannii K.Krause
Cuviera sp.
Dictyandra arborescens Hook.f.
Diodia sp.
Ecpoma hiernianum (Wernh.) N. & F.Hallé
Gardenia ternifolia Schum. & Thonn. ssp. *jovis-tonantis* (Welw.) Verdc.
Geophila afzelii Hiern
Geophila obvallata (Schum.) F.Didr.
Hallea ledermannii (K.Krause) Verdc.
Heinsia crinita (Afzel.) G.Taylor
Hymenodictyon biafranum Hiern
Ixora aneimenodesma K.Schum. ssp. *kizuensis* De Block
Ixora hippoperifera K.Schum.
Ixora nematopoda K.Schum.
Ixora praetermissa De Block
Keetia sp.
Lasianthus batangensis K.Schum.
Leptactina arnoldiana De Wild.
Leptactina laurentiana Dewevre
Massularia acuminata (G.Don) Bullock ex Hoyle
Morinda longiflora G.Don
Morinda morindoides (Baker) Milne-Redh.
Mussaenda polita Hiern
Mussaenda tenuiflora Benth.
Pauridiantha canthiiflora Hook.f.
Pauridiantha mayumbensis (R.Good) Bremek.
Pausinystalia johimbe (K.Schum.) Pierre ex Dup. & Beille
Pausinystalia macroceras (K.Schum.) Pierre
Pavetta corymbosa (DC.) F.N.Williams var. *neglecta* Bremek.

Pseudosabicea aurifodinae N.Hallé
Pseudosabicea mildbraedii (Wernh.) N.Hallé
Pseudosabicea mitisphaera N.Hallé
Psychotria fimbriatifolia R.Good
Psychotria venosa (Hiern) Petit
Psydrax arnoldiana (De Wild. & Th.Dur.) Bridson
Rothmannia liebrechtsiana (De Wild. & Th.Dur.) Keay
Rothmannia whitfieldii (Lindl.) Dandy
Rutidea sp.
Rytigynia rubra Robyns
Rytigynia verruculosa (Krause) Robyns
Sabicea calycina Benth.
Sabicea duparquetiana Baill. ex Wernh.
Sarcocephalus latifolius (Smith) Bruce
Schumanniophyton hirsutum (Hiern) R.Good
Schumanniophyton magnificum (K.Schum.) Harms
Sericanthe pellegrinii (N.Hallé) Robbrecht
Sericanthe petitii (N.Hallé) Robbrecht
Sherbournia curvipes (Wernh.) N.Hallé
Stipularia africana P.Beauv.
Tarenna jolinonii N.Hallé
Tarenna lasiorachis (K.Schum. & K.Krause) Bremek.
Tricalysia pallens Hiern
Tricalysia soyauxii K.Schum.
Trichostachys sp.
Uncaria africana G.Don var. *angolensis* Havil.
Vangueriella rufa (Robyns) Verdc.
Vangueriopsis rubiginosa Robyns
Virectaria procumbens (Sm.) Bremek.

RUTACEAE (5)
Araliopsis soyauxii Engl.
Clausena anisata (Willd.) Hook.f. ex Benth.
Zanthoxylum gilletii (De Wild.) Waterman
Zanthoxylum heitzii (Aubrév. & Pellegr.) Waterman
Zanthoxylum lemairei (De Wild.) Waterman

SAPINDACEAE (15)
Allophylus cobbe (L.) Räusch.
Chytranthus angustifolius Exell
Chytranthus macrobotrys (Gig) Exell & Mendonça
Chytranthus mortehanii (De Wild.) De Vold. ex Hauman
Chytranthus talbotii (Bak.f.) Keay
Deinbollia maxima Gilg
Eriocoelum kerstingii Gilg ex Engl.
Eriocoelum paniculatum Baker
Eriocoelum racemosum Baker
Ganophyllum giganteum (A.Chev.) Hauman

Laccodiscus sp.
Pancovia floribunda Pellegr.
Paullinia pinnata L.
Placodiscus boya Aubrév. & Pellegr.
Placodiscus opacus Radlk.

SAPOTACEAE (11)
Autranella congolensis (De Wild.) A.Chev.
Chrysophyllum pruniforme Pierre ex Engl.
Chrysophyllum subnudum Baker
Gambeya africana (A.DC.) Pierre
Letestua durissima (A.Chev.) Lecomte
Manilkara fouilloyana Aubrév. & Pellgr.
Omphalocarpum sp.
Synsepalum longecuneatum De Wild.
Tieghemella africana Pierre
Zeyherella letestui Aubrév. & Pellegr.
Zeyherella mayombense (Greves) Aubrév. & Pellegr.

SCROPHULARIACEAE (3)
Lindernia senegalensis (Benth.) Stau
Scoparia dulcis L.
Sopubia simplex (Hochst.) Hochst.

SCYTOPETALACEAE (5)
Brazzeia congoensis Baill.
Brazzeia soyauxii (Oliv.) Tiegh. var. *soyauxii*
Oubanguia africana Baill.
Rhaptopetalum coriaceum Oliv.
Scytopetalum klaineanum Pierre ex Engl.

SIMAROUBACEAE (3)
Nothospondias staudtii Engl.
Odyendyea gabonensis (Pierre) Engl.
Quassia africana (Baill.) Baill.

SOLANACEAE (3)
Capsicum annuum L.
Capsicum frutescens A.Br. & Bouch
Solanum torvum Sw.

STERCULIACEAE (15)
Cola acuminata (P.Beauv.) Schott & Endl.
Cola altissima Engl.
Cola crispiflora K.Schum.
Cola digitata Mast.
Cola duparquetiana Baill.
Cola flavovelutina K.Schum.

Cola lateritia K.Schum.
Cola rostrata K.Schum.
Leptonychia bampsii Germ. var. *ituriensis* Germ.
Leptonychia echinocarpa K.Schum.
Nesogordonia papaverifera (A.Chev.) Cap.
Scaphopetalum blackii Mast.
Scaphopetalum macranthum K.Schum.
Scaphopetalum thonneri De Wild. & Th.Dur.
Sterculia tragacantha Lindl.

THYMELAEACEAE (4)
Craterosiphon sp.
Dicranolepis disticha Planch.
Dicranolepis soyauxii Engl.
Octolepis decalepis Gilg

TILIACEAE (10)
Ancistrocarpus densispinosus Oliv.
Clappertonia ficifolia (Willd.) Decne
Desplatsia dewevrei (De Wild. & Th.Dur.) Burret
Desplatsia subericarpa Bocq.
Glyphaea brevis (Spreng.) Monachino
Grewia coriacea Mast.
Grewia flavescens Juss.
Grewia mollis Juss.
Triumfetta cordifolia A.Rich.
Triumfetta pentandra A.Rich.

ULMACEAE (3)
Celtis mildbraedii Engl.
Celtis philippensis Blanco
Celtis tessmannii Rendle

URTICACEAE (5)
Boehmeria macrophylla Hornem.
Boehmeria platyphylla D.Don ex Hamilton
Laportea ovalifolia (Schum. & Thonn.) Chew
Urera repens (Wedd.) Rendle
Urera trinervis (Hochst.) Friis & Immelman

VERBENACEAE (8)
Clerodendrum bipindense Gürke
Clerodendrum buettneri Gürke
Lantana camara L.
Lippia multiflora Moldenke
Premna angolensis Gürke
Stachytarpheta indica (L.) Vahl
Vitex doniana Sweet

Vitex grandifolia Gürke

VIOLACEAE (20)
Decorsella paradoxa A.Chev.
Rinorea albidiflora Engl.
Rinorea angustifolia (Thouars) Grey-Wilson
Rinorea batesii Chipp
Rinorea brachypetala (Turcz.) Kuntze
Rinorea breviracemosa Chipp
Rinorea cerasifolia M.Brandt
Rinorea cymulosa Kuntze
Rinorea dentata (P.Beauv.) Kuntze
Rinorea ebolowensis M.Brandt
Rinorea ilicifolia (Welw. ex Oliv.) Kuntze
Rinorea johnstonii Chipp
Rinorea mildbraedii M.Brandt
Rinorea oblongifolia (C.H. Wright) Marquand ex Chipp
Rinorea oppositifolia Exell
Rinorea parviflora Chipp
Rinorea subintegrifolia (P. Beauv.) Kuntze
Rinorea subsessilis Brandt
Rinorea talbotii (Baker f.) De Wild.
Rinorea welwitschii (Oliv.) Kuntze

VITACEAE (12)
Ampelocissus cavicaulis (Baker) Planch.
Cissus barbeyana De Wild. & Th.Dur.
Cissus diffusiflora (Baker) Planch.
Cissus dinklagei Gilg & Brandt
Cissus leonardii De Wit
Cissus petiolata Hook.f.
Cissus planchoniana Gilg
Cissus producta Afzel.
Cissus ruginosicarpa Desc.
Cissus smithiana (Baker) Planch.
Cyphostemma ukerewense (Gilg) Desc. var. *gabonicum* Desc.
Leea guineensis G.Don

VOCHYSIACEAE (1)
Erismadelphus exsul Mildbr.

MONOCOTYLEDONAE
    AMARYLLIDACEAE (2)
    Crinum jagus (Thomps.) Dandy
    Scadoxus sp.

    ARACEAE (7)
    Anchomanes difformis (Blume) Engl.

Anubias barteri Schott var. *glabra* N.E.Br.
Anubias heterophylla Engl.
Culcasia panduriformis Engl. & K.Krause
Culcasia parviflora N.E.Br.
Nephthytis afzelii Schott
Nephthytis swainei Bogner

BURMANNIACEAE (1)
Gymnosiphon longistylus (Benth.) Hutch.

COMMELINACEAE (16)
Aneilema beniniense (P.Beauv.) Kunth
Aneilema dispermum Brenan
Aneilema umbrosum (Vahl) Kunth
Commelina cameroonensis J.K.Morton
Commelina diffusa Burm.f.
Commelina longicapsa C.B.Clarke
Cyanotis sp.
Floscopa africana (P.Beauv.) C.B.Clarke ssp. *petrophila* J.K.Morton
Palisota ambigua (P.Beauv.) C.B.Clarke
Palisota hirsuta (Thunb.) K.Schum.
Palisota lagopus Mildbr.
Palisota mannii C.B.Clarke
Pollia condensata C.B.Clarke
Pollia mannii C.B.Clarke
Polyspatha paniculata Benth.
Stanfieldiella imperforata (C.B.Clarke) Brenan

CYPERACEAE (19)
Bulbostylis laniceps C.B.Clarke ex Dur. & Schinz
Cyperus angolensis Boeck.
Cyperus articulatus L.
Cyperus difformis L.
Cyperus distans L.f.
Cyperus fertilis Boeck.
Cyperus mapanioides C.B.Clarke
Cyperus renschii Boeck.
Eleocharis acutangula (Roxb.) Schult.
Fuirena umbellata Rottb.
Hypolytrum lancifolium C.B.Clarke
Hypolytrum purpurascens Cherm.
Kyllinga odorata Vahl
Mapania amplivaginata K.Schum.
Mapania mannii C.B.Clarke
Scleria naumanniana Boeck.
Scleria pterota Presl
Scleria verrucosa Willd.
Scleria vogelii C.B.Clarke

DIOSCOREACEAE (4)
Dioscorea cayenensis Lam.
Dioscorea minutiflora Engl.
Dioscorea preussii Pax
Dioscorea semperflorens Uline

DRACAENACEAE (1)
Dracaena mannii Baker

GRAMINEAE (40)
Acroceras gabunense (Hack.) Clayton
Acroceras zizanioides (Kunth) Dandy
Anadelphia afzeliana (Rendle) Stapf
Andropogon chinensis (Nees) Merr.
Andropogon gayanus Kunth var. *polycladus* (Hack.) Clayton
Axonopus compressus (Sw.) P.Beauv.
Centotheca lappacea (L.) Desv.
Ctenium newtonii Hack.
Cyrtococcum chaetophorum (Roem. & Schult.) Dandy
Digitaria leptorhachis (Pilg.) Stapf
Elymandra gossweileri (Stapf) Clayton
Hyparrhenia familiaris (Steud.) Stapf
Hyparrhenia filipendula (Hochst.) Stapf
Imperata cylindrica (L.) Beauv.
Leptaspis zeylanica Nees ex Steud.
Megastachya mucronata (Poir.) P.Beauv.
Olyra latifolia L.
Oplismenus burmannii (Retz.) P.Beauv.
Oplismenus hirtellus (L.) P.Beauv.
Panicum brazzavillense Franch.
Panicum brevifolium L.
Panicum griffonii Franch.
Panicum laxum Sw.
Panicum maximum Jacq.
Panicum phragmitoides Stapf
Paspalum conjugatum Berg.
Paspalum paniculatum L.
Paspalum scrobiculatum L.
Paspalum virgatum L.
Pennisetum polystachion (L.) Schult. ssp. *polystachion*
Pennisetum unisetum (Nees) Benth.
Perotis indica (L.) Kuntze
Rottboellia cochinchinensis (Lour.) Clayton
Schizachyrium brevifolium (Sw.) Büse
Setaria homonyma (Steud.) Chiov.
Setaria megaphylla (Steud.) Dur. & Schinz
Sporobolus indicus (L.) R.Br. var. *pyramidalis* (P.Beauv.) Veldk.
Streptogyna crinita P.Beauv.

Urochloa brizantha (A.Rich.) R.D.Webster

LILIACEAE (3)
Asparagus sp.
Chlorophytum sparsiflorum Baker
Chlorophytum togoense Engl.

MARANTACEAE (8)
Ataenidia conferta (Benth.) Milne-Redh.
Hypselodelphys sp.
Marantochloa congensis (K.Schum.) J.Léonard & Mullenders var. *pubescens*
    J.Léonard & Mullenders
Marantochloa filipes (Benth.) Hutch.
Megaphrynium macrostachyum (Benth.) Milne-Redh.
Megaphrynium trichogynum Koechlin
Sarcophrynium sp.
Trachyphrynium braunianum (K.Schum.) Baker

ORCHIDACEAE (28)
Ancistrorhynchus capitatus (Lindl.) Summerh.
Ancistrorhynchus recurvus Finet
Angraecum podochiloides Schltr.
Bulbophyllum intertextum Lindl.
Bulbophyllum ivorense Cribb & Perez-Vera
Bulbophyllum oreonastes Rchb.f.
Bulbophyllum pumilum (Sw.) Lindl.
Bulbophyllum saltatorium Lindl. var. *distans* (Lindl.) J.J.Verm.
Calyptrochilum christyanum (Rchb.f.) Summerh.
Chamaeangis ichneumonea (Lindl.) Schltr.
Cynorkis debilis (Hook.f.) Summerh.
Cyrtorchis ringens (Rchb.f.) Summerh.
Diaphananthe bidens (Sw.) Schltr.
Diaphananthe rutila (Rchb.f.) Summerh.
Eulophia euglossa Rchb.f.
Habenaria stenochila Lindl.
Liparis tridens Kraenzl.
Listrostachys pertusa (Lindl.) Rchb.f.
Manniella gustavii Rchb.f.
Microcoelia microglossa Summerh.
Polystachya concreta (Jacq.) Garey & Sweet
Polystachya paniculata (Sw.) Rolfe
Polystachya polychaete Kraenzl.
Polystachya seticaulis Rendle
Summerhaysia laurentii (De Wild.) Cribb
Tridactyle anthomaniaca (Rchb.f.) Summerh.
Zeuxine elongata Rolfe
Zeuxine occidentalis (Summerh.) Geerinck

PALMAE (3)
Eremospatha macrocarpa G.Mann & H.Wendl.
Laccosperma opacum (G.Mann & H.Wendl.) Drude
Laccosperma secundiflora (P.Beauv.) Kuntze

TECOPHILAEACEAE (1)
Cyanastrum cordifolium Oliv.

ZINGIBERACEAE (8)
Aframomum limbatum (Oliv. & Hanb.) K.Schum.
Costus engleranus K.Schum.
Costus fissiligulatus Gagnep.
Costus gabonensis Koechlin
Costus lateriflorus Baker
Costus nudicaulis Baker
Renealmia cincinnata (K.Schum.) Baker
Renealmia macrocolea K.Schum.

PTERIDOPHYTAE

ADIANTACEAE (1)
Pityrogramma calomelanos (L.) Link

ASPLENIACEAE (10)
Asplenium africanum Desv.
Asplenium barteri Hook.
Asplenium gemmascens Alston
Asplenium hemitomum Hieron.
Asplenium jaundeense Hieron.
Asplenium rutifolium (Berg) Kunze
Asplenium subintegrum C.Chr.
Asplenium theciferum (Kunth) Mett.
Asplenium variabile Hook. var. *paucijugum* (Ballard) Alston
Asplenium variabile Hook. var. *variabile*

CYATHEACEAE (1)
Cyathea camerooniana Hook. var. *zenkeri* (Hieron. ex Diels) Tardieu-Blot

DENNSTAEDTIACEAE (3)
Blotiella currori (Hook.) Tyron
Microlepia speluncae (L.) Moore
Pteridium aquilinum (L.) Kuhn

DRYOPTERIDACEAE (11)
Diplazium welwitschii (Hook.) Diels
Lastreopsis subsimilis (Hook.) Tindale
Tectaria angelicifolia (Schum.) Copel.
Tectaria fernandensis (Baker) C.Chr.
Triplophyllum dimidiatum (Mett. ex Kuhn) Holttum

Triplophyllum gabonense Holttum
Triplophyllum pilosissimum (Moore) Holttum
Triplophyllum securidiforme (Hook.) Holttum var. *securidiforme*
Triplophyllum speciosum (Mett.) Holttum
Triplophyllum troupinii (Pic.Serm.) Holttum
Triplophyllum vogelii (Hook.) Holttum

GLEICHENIACEAE (1)
Dicranopteris linearis (Burm.) C.B.Clarke

HYMENOPHYLLACEAE (3)
Hymenophyllum kuhnii C.Chr.
Trichomanes crenatum Bosch
Trichomanes cupressoides Desv.

LOMARIOPSIDACEAE (3)
Elaphoglossum barteri (Baker) C.Chr.
Lomariopsis hederacea Alston
Lomariopsis rossii Holttum

LYCOPODIACEAE (3)
Huperzia staudtii (Nessel) Pic.Serm.
Lycopodiella cernua (L.) Pic.Serm.
Lycopodium sp.

MARATTIACEAE (1)
Marattia sp.

OLEANDRACEAE (4)
Arthropteris monocarpa (Cordem.) C.Chr.
Nephrolepis biserrata (Sw.) Schott
Nephrolepis undulata (Afzel. ex Sw.) J.Sm.
Oleandra distenta Kunze

PARKERIACEAE (1)
Ceratopteris cornuta (P.Beauv.) Lepr.

POLYPODIACEAE (6)
Drynaria laurentii (Christ.) Hieron.
Microgramma owariensis (Desv.) Alston
Microsorium punctatum (L.) Copel
Phymatosorus scolopendria (Burm.) Ching
Platycerium stemaria (P.Beauv.) Desv.
Polypodium owariense Desv.

PTERIDACEAE (1)
Pteris mildbraedii Hieron.

SCHIZAEACEAE (1)
Lygodium sp.

SELAGINELLACEAE (1)
Selaginella sp.

THELYPTERIDACEAE (1)
Thelypteris pauciflora (Hook.) Reed

VITTARIACEAE (2)
Antrophyum mannianum Hook.
Vittaria guineensis Desv.

APPENDIX B

BIODIVERSITY CATEGORIES AND VALUES FOR ALL SPECIES OF THE 11 SELECTED FAMILIES

ABBREVIATIONS:
Fl.Afr.Centr.: Flore de l'Afrique Centrale
Fl.Cam.: Flore du Cameroun
Fl.Gab.: Flore du Gabon
FTEA: Flora of Tropical East Africa
FWTA: Flora of West Tropical Africa

Acanthaceae (27 species)	Reference	Biodiversity category	Biodiversity value
Adhatoda buchholzii (Lindau) S.Moore	Fl.Gab.; FWTA	2B	9
Adhatoda le-testui (R.Benoist) Heine	Fl.Gab.	1A	81
Anisosepalum alboviolaceum (R.Benoist) E. Hossain	Champluvier, 1991	3B	3
Anisotes macrophyllus (Lindau) Heine	Fl.Gab.	3B	3
Asystasia gangetica (L.) T.Anderson	Fl.Gab.	5	1
Brillantaisia soyauxii Lindau	Fl.Gab.	2B	9
Brillantaisia vogeliana (Nees) Benth.	Fl.Gab.; FWTA	4B	1
Dicliptera verticillata (Forsk.) C.Christ.	Fl.Gab.	5	1
Elytraria marginata Vahl	FWTA	5	1
Hypoestes forskaolii (Vahl) R.Br.	Fl.Gab.	5	1
Justicia bolomboensis De Wild.	Fl.Gab.	3B	3
Justicia claessensii De Wild.	Fl.Gab.	3B	3
Justicia laxa T.Anderson	Fl.Gab.; FWTA	3B	3
Justicia tenella (Nees) T.Anderson	Fl.Gab.	5	1
Nelsonia canescens (Lam.) Spreng.	Morton, 1979	5	1
Phaulopsis angolana S.Moore	Fl.Gab.	4B	1
Physacanthus batanganus (G.Braun & K. Schum.) Lindau	Fl.Gab.; FWTA	3B	3
Physacanthus nematosiphon (Lindau) Rendle & Britten	Fl.Gab.; FWTA	3B	3
Pseuderanthemum tunicatum (Afzel.) Milne-Redh.	Fl.Gab.	5	1
Rhinacanthus virens (Nees) Milne-Redh.	Fl.Gab.	3B	3
Saintpauliopsis lebrunii Staner	Champluvier 1991	4A	3
Staurogyne letestuana R.Benoist	Champluvier, 1991	2B	9
Stenandrium gabonicum (R.Benoist) Vollesen	Vollesen, 1992	2A	27
Stenandrium guineense (Nees) Vollesen	Vollesen, 1992	5	1
Stenandrium talbotii (S.Moore) Vollesen	Vollesen, 1992	2B	9
Thomandersia butayei De Wild.	Fl.Gab.; Heine, 1966	3B	3
Thomandersia hensii De Wild. & Th.Dur.	Fl.Gab.; Heine, 1966	3B	3

Apocynaceae (29 species)	Reference	Biodiversity category	Biodiversity value
Callichilia bequaertii De Wild.	Beentje, 1978	3B	3
Calocrater preussii K.Schum.	Leeuwenb., 1995	2B	9
Cyclocotyla congolensis Stapf	Ploeg, 1985	3B	3
Cylindropsis parvifolia Pierre	Haegens, 1994	3B	3
Dictyophlebia ochracea (K.Schum. ex Hallier f.) Pichon	Hoogh, 1992	3B	3
Holarrhena floribunda (G.Don) Dur. & Schinz	Kruif, 1981	4B	1
Hunteria umbellata (K.Schum.) Hallier f.	Omino, 1996	3A	9
Landolphia congolensis (Stapf) Pichon	Persoon et al., 1992	3B	3
Landolphia dewevrei Stapf	Persoon et al., 1992	3B	3
Landolphia foretiana (Pierre ex Jum.) Pichon	Persoon et al., 1992	4B	1
Landolphia glabra (Pierre ex Stapf) Pichon	Persoon et al., 1992	3B	3
Landolphia incerta (K.Schum.) Persoon	Persoon et al., 1992	4B	1
Landolphia mannii Dyer	Persoon et al., 1992	3B	3
Landolphia owariensis P.Beauv.	Persoon et al., 1992	5	1
Landolphia pyramidata (Pierre) Persoon	Persoon et al., 1992	1A	81
Landolphia reticulata Hallier f.	Persoon et al., 1992	1B	27
Landolphia robustior (K.Schum.) Persoon	Persoon et al., 1992	3B	3
Orthopichonia cirrhosa (Radlk.) H.Huber	Vonk, 1989	2B	9
Picralima nitida (Stapf) Th. & H.Dur.	Omino, 1996	4B	1
Pleiocarpa rostrata Benth.	Omino, 1996	2B	9
Rauvolfia letouzeyi Leeuwenb.	Dilst & Leeuwenb., 1991	1B	27
Rauvolfia mannii Stapf	Dilst & Leeuwenb., 1991	5	1
Rauvolfia vomitoria Afzel.	Dilst & Leeuwenb., 1991	5	1
Tabernaemontana bouquetii (Boiteau) Leeuwenb.	Leeuwenb, 1991	1B	27
Tabernaemontana crassa Benth.	Leeuwenb., 1991	4B	1
Tabernaemontana letestui (Pellegr.) Pichon	Leeuwenb., 1991	2B	9
Tabernanthe iboga Baill.	Vonk & Leeuwenb., 1989	3B	3
Voacanga bracteata Stapf	Leeuwenb., 1985	4B	1
Voacanga psilocalyx Pierre ex Stapf	Leeuwenb., 1985	2B	9

Balsaminaceae (5 species)	Reference	Biodiversity category	Biodiversity value
Impatiens floretii N.Hallé & A.M.Louis	Hallé & Louis, 1989	1A	81
Impatiens gossweileri G.M.Schulze	Grey-Wilson, 1980	2A	27
Impatiens hians Hook.f.	Grey-Wilson, 1980	3B	3
Impatiens niamniamensis Gilg	Grey-Wilson, 1980	4B	1
Impatiens palpebrata Hook.f.	Grey-Wilson, 1980	2B	9

Begoniaceae (27 species)	Reference	Biodiversity category	Biodiversity value
Begonia auriculata Hook.f.	Wieringa, ms.	4B	1
Begonia capillipes Gilg	Wilde, 2002	2B	9
Begonia clypeifolia Hook.f.	Sosef, 1994	1B	27
Begonia dewildei Sosef	Sosef, 1994	1A	81
Begonia eboloensis Engl.	Wilde, 2002	2B	9
Begonia elaeagnifolia Hook.f.	Arends, 1992	2B	9
Begonia elatostemmoides Hook.f.	Wieringa, ms.	2B	9
Begonia fusialata Warb	Wilde, 2002	5	1
Begonia gabonensis J.J.de Wilde	Wilde, 2002	1A	81
Begonia hirsutula Hook.f.	Sosef, 1994	4B	1
Begonia komoensis Irmsch.	Wilde, 2002,	1B	27
Begonia lacunosa Warb.	Sosef, 1994	2B	9
Begonia letouzeyi Sosef	Sosef, 1994	2A	27
Begonia longipetiolata Gilg	Arends, 1992	3B	3
Begonia loranthoides Hook.f.	Wilde & Arends, 1979	3B	3
Begonia macrocarpa Warb.	Wieringa, ms.	4B	1
Begonia mannii Hook.	Wilde, 2002,	3B	3
Begonia mildbraedii Gilg	Sosef, 1994	4B	1
Begonia poculifera Hook.f.	Wilde & Arends, 1980	4B	1
Begonia polygonoides Hook.f.	Wilde, 2002	4B	1
Begonia sciaphila Gilg ex Engl.	Wieringa, ms.	2B	9
Begonia scutifolia Hook.f.	Sosef, 1994	2B	9
Begonia scutulum Hook.f.	Sosef, 1994	1B	27
Begonia vankerckhovenii De Wild.	Sosef, 1994	3A	9

70

Caesalpiniaceae (56 species)	Reference	Biodiversity category	Biodiversity value
Anthonotha acuminata (De Wild.) J.Léonard	Fl.Gab.; Fl.Afr.Centr.	3B	3
Anthonotha ferruginea (Harm) J.Léonard	Fl.Gab.; Fl.Cam.	2B	9
Anthonotha fragrans (Bak.f.) Exell & Hillcoat	Fl.Gab.	4B	1
Anthonotha macrophylla P.Beauv.			
Anthonotha pynaertii (De Wild.) Exell & Hillcoat	Fl.Gab.	4B	1
Anthonotha trunciflora (Harms) J.Léonard	Fl.Gab.; Fl.Afr.Centr.	3B	3
Aphanocalyx heitzii (Pellegr.) Wieringa	Fl.Gab.	1A	81
Aphanocalyx microphyllus (Harms) Wieringa	Wieringa, 1999	1B	27
Baikiaea insignis Benth.	Wieringa, 1999	3B	3
Berlinia auriculata Benth.	Fl.Gab.	2B	9
Berlinia bracteosa Benth.	Fl.Gab.	2B	9
Berlinia confusa Hoyle	Fl.Gab.	2B	9
Bikinia coriacea (J.Morel ex Aubrév.) Wieringa	Fl.Gab.	3B	3
	Wieringa, 1999	1B	27
Bikinia letestui (Pellegr.) Wieringa			
Bobgunnia fistuloides (Harms) Kirkbr. & Wiersema	Wieringa, 1999	2B	9
	Fl.Gab.	3B	3
Brachystegia mildbraedii Harms			
Cassia chamaecrista L.	Fl.Gab.	2B	9
Cassia hirsuta L.	FTEA	(cult.)	–
Cassia mannii Oliv.	Fl.Gab.	5	1
Chamaecrista absus (L.) Irwin & Barneby	Fl.Gab.; FTEA	5	1
Copaifera religiosa J.Léonard	FTEA	5	1
Crudia harmsiana De Wild.	Fl.Gab.	2B	9
Cynometra lujae De Wild.	Fl.Afr.Centr.	2B	9
	Fl.Gab.; Fl.Afr.Centr.	2B	9
Cynometra mannii Oliv.			
	Fl.Gab.; Fl.Afr.Centr.	2B	9
Cynometra nyangensis Pellegr.			
Daniellia klainei Pierre ex A.Chev.	Fl.Gab.	1A	81
Daniellia soyauxii (Harms) Rolfe	Fl.Gab.; Fl.Cam.	2B	9
	Fl.Gab.; Fl.Afr.Centr.	3B	3
Dialium angolense Welw. Ex Oliv.			
Dialium bipindense Harms	Breteler, 1993	3B	3
	Fl.Gab.; Rojo 1982	2B	9
Dialium dinklagei Harms			
Dialium guineense Willd.	Fl.Gab.	4B	1
Didelotia africana Baill.	Breteler, 1993	3B	3
Didelotia brevipaniculata J.Léonard	Fl.Gab.	2B	9
Distemonanthus benthamianus Baill.	Fl.Gab.; Fl.Cam.	3B	3
Gilbertiodendron brachystegioides (Harms) J. Léonard	Fl.Gab.	3B	3
	Fl.Gab.	2B	9
Gilbertiodendron ogoouense (Pellegr.) J. Léonard	Fl.Gab.	2B	9
Gilbertiodendron stipulaceum (Benth.) J. Léonard	Fl.Gab.	2B	9
Gilbertiodendron unijugum (Harms) J. Léonard	Fl.Gab	1B	27

Caesalpiniaceae (continued)	Reference	Biodiversity category	Biodiversity value
Griffonia physocarpa Baill.	Fl.Gab.	3B	3
Guibourtia ehie (A.Chev.) J.Léonard	Fl.Gab.; Fl.Cam.	3B	3
Guibourtia tessmannii (Harms) J.Léonard	Fl.Gab.	2B	9
Hylodendron gabunense Taub.	Fl.Gab.	3B	3
Hymenostegia floribunda (Benth.) Harms	Fl.Gab.;Fl. Afr.Centr.	2B	9
Hymenostegia klainei Pierre ex Pellegr.	Fl.Gab.	1B	27
Hymenostegia ngounyensis Pellegr.	Fl.Gab.	1B	27
Isomacrolobium conchyliophorum (Pellegr.) Aubrév. & Pellegr.	Fl.Gab.	1A	81
Julbernardia brieyi (De Wild.) Troupin	Fl.Gab.	2A	27
Librevillea klainei (Pierre ex Harms) Hoyle	Fl.Gab.	2B	9
Neochevalierodendron stephanii (A.Chev.) J. Léonard	Fl.Gab.	2B	9
Oddoniodendron micranthum (Harms) Baker	Fl.Gab.	2B	9
Plagiosiphon emarginatus (Hutch. & Dalz.) J. Léonard	Fl.Gab.	3B	3
Scorodophloeus zenkeri Harms	Fl.Gab.; Fl.Afr.Centr.	3B	3
Senna alata (L.) Roxburgh.	Fl.Gab.	5	1
Senna timoriensis (DC.) Irwin & Barneby	FTEA	(cult.)	–
Tetraberlinia bifoliolata (Harms) Hauman	Wieringa, 1999	2B	9
Tetraberlinia polyphylla (Harms) J.Léonard	Wieringa, 1999	1B	27

Combretaceae (8 species)	Reference	Biodiversity category	Biodiversity value
Combretum aphanopetalum Engl. & Diels	Fl.Gab.	3B	3
Combretum bracteatum (Laws.) Engl. & Diels	Fl.Gab.	4B	1
Combretum falcatum (Welw. ex Hiern) Jongk.	Fl.Gab.	4B	1
Combretum mannii Engl. & Diels	Fl.Gab.	3B	3
Combretum paniculatum Vent.	Fl.Gab.	5	1
Combretum rabiense Jongkind	Fl.Gab.	1B	27
Combretum racemosum P.Beauv.	Fl.Gab.	4B	1
Strephonema sericeum Hook.f.	Fl.Gab.; Jongkind, 1995	3B	3

Connaraceae (17 species)	Reference	Biodiversity category	Biodiversity value
Agelaea paradoxa Gilg		4B	1
Agelaea pentagyna (Lam.) Baill.		5	1
Agelaea poggeana Gilg		3B	3
Cnestis corniculata Lam.		5	1
Cnestis ferruginea Vahl ex DC.		4B	1
Connarus longistipitatus Gilg		4A	3
Hemandradenia mannii Stapf		4B	1
Jollydora duparquetiana (Baill.) Pierre	All are Jongkind & Lemmens, 1989	2B	9
Manotes expansa Sol. ex Planch.		4B	1
Manotes griffoniana Baill.		3B	3
Manotes macrantha (Gilg) Schellenb.		3B	3
Rourea minor (Gaertn.) Alston		5	1
Rourea myriantha Baill.		3B	3
Rourea obliquifoliolata Gilg		3B	3
Rourea parviflora Gilg		3B	3
Rourea solanderi Baker		4B	1
Rourea thomsonii (Baker) Jongkind		5	1

Dichapetalaceae (17 species)	Reference	Biodiversity category	Biodiversity value
Dichapetalum choristilum Engl.	Breteler, 1978	4B	1
Dichapetalum congoense Engl. & Ruhl.	Breteler, 1978	3B	3
Dichapetalum dewevrei De Wild. & Th.Dur.	Breteler, 1978	3B	3
Dichapetalum fructuosum Hiern	Breteler, 1978	4A	3
Dichapetalum gabonense Engl.	Breteler, 1979	2B	9
Dichapetalum glomeratum Engl.	Breteler, 1979	3B	3
Dichapetalum heudelotii (Planch. Ex Oliv.) Baill.	Breteler, 1979	4B	1
Dichapetalum insigne Engl.	Breteler, 1979	2B	9
Dichapetalum integripetalum Engl.	Breteler, 1979	2B	9
Dichapetalum lujae De Wild. & Th.Dur.	Breteler, 1979	3B	3
Dichapetalum madagascariense Poir.	Breteler, 1981	5	1
Dichapetalum melanocladum Breteler	Breteler, 1981	2B	9
Dichapetalum minutiflorum Engl. & Ruhl.	Breteler, 1981	2B	9
Dichapetalum parvifolium Engl.	Breteler, 1981	4B	1
Dichapetalum zenkeri Engl.	Breteler, 1982	4B	1
Dichapetalum spec. nov.	Breteler, verbal	1A	81
Tapura letestui Pellegr.	Breteler, 1986	1A	81

Melastomataceae (29 species)	Reference	Biodiversity category	Biodiversity value
Amphiblemma ciliatum Cogn.	Fl.Gab.	3B	3
Amphiblemma molle Hook.f.	Fl.Gab.	2B	9
Amphiblemma setosum Hook.f.	Fl.Gab.	1B	27
Calvoa hirsuta Hook.f.	Jacq.-Fél., 1981	4B	1
Calvoa orientalis Taub.	Jacq.-Fél., 1981	4B	1
Calvoa pulcherrima Gilg ex Engl.	Jacq.-Fél., 1981	2B	9
Calvoa seretii De Wild.	Jacq.-Fél., 1981	3B	3
Cincinnobotrys acaulis (Cogn.) Gilg	Jacq.-Fél., 1976	3A	9
Dicellandra barteri Hook.f.	Fl.Gab.	3B	3
Dicellandra descoingsii Jacq.-Fél.	Fl.Gab.	1B	27
Dinophora spenneroides Benth.	Fl.Gab.; Fl.Cam.	4B	1
Dissotis brazzae Cogn.	Fl.Gab.	4B	1
Dissotis congolensis (Cogn. ex Buettn.) Jacq.-Fél.	Fl.Gab.	5	1
Dissotis multiflora (Sm.) Triana	Fl.Gab.	3B	3
Heterotis decumbens (P.Beauv.) Jacq.-Fél.	Fl.Gab.; Fl.Cam.	4B	1
Medinilla mannii Hook.f.	Fl.Gab.	3A	9
Medinilla mirabilis (Gilg) Jacq.-Fél.	Fl.Gab.; Fl.Cam.	3B	3
Memecylon calophyllum Gilg	Fl.Gab.; Fl.Cam.	2B	9
Memecylon collinum Jacq.-Fél.	Fl.Gab.; Jacq.-Fél., 1979	2A	27
Memecylon klaineanum Jacq.-Fél.	Fl.Gab.; Jacq.-Fél., 1979	2B	9
Memecylon lateriflorum (G.Don) Bremek.	Fl.Gab.; FWTA	3B	3
Memecylon salicifolium Jacq.-Fél.	Fl.Gab.	1A	81
Preussiella kamerunensis Gilg	Fl.Gab.	3B	3
Tristemma oreophilum Gilg	Fl.Gab.	3A	9
Tristemma vestitum Jacq.-Fél.	Jacq.-Fél., 1986	1A	81
Warneckea cauliflora Jacq.-Fél.	Fl.Gab.	1A	81
Warneckea floribunda Jacq.-Fél.	Fl.Gab.	3B	3
Warneckea membranifolia (Hook.f.) Jacq.-Fél.	Fl.Gab.; Fl.Cam.	4B	1
Warneckea sapinii (De Wild.) Jacq.-Fél.	Fl.Gab.	3A	9

Mimosaceae (19 species)	Reference	Biodiversity category	Biodiversity value
Acacia auriculiformis A.Cunn. ex Benth.	Fl.Gab.	(cult.)	–
Aubrevillea platycarpa Pellegr.	Fl.Gab.	3B	3
Calpocalyx brevifolius Villiers	Villiers, 1984	1A	81
Calpocalyx dinklagei Harms	Villiers, 1984	2B	9
Calpocalyx heitzii Pellegr.	Villiers, 1984	2B	9
Cylicodiscus gabonensis Harms	Fl.Gab.	3B	3
Dichrostachys cinerea (L.) Wight & Arn.	Fl.Gab.	5	1
Entada gigas (L.) Fawcett & Rendle	Fl.Gab.	5	1
Fillaeopsis discophora Harms	Fl.Gab.	3B	3
Mimosa pigra L.	Fl.Gab.	5	1
Newtonia griffoniana (Baill.) Bak.f.	Villiers, 1990	3B	3
Newtonia leucocarpa (Harms) Gilbert & Boutique	Villiers, 1990	3B	3
Parkia bicolor A.Chev.	Fl.Gab.	4B	1
Parkia filicoidea Welw. ex Oliv.	Fl.Gab.	4B	1
Pentaclethra eetveldeana De Wild. & Th.Dur.	Fl.Gab.	2B	9
Pentaclethra macrophylla Benth.	Fl.Gab.	4B	1
Piptadeniastrum africanum (Hook.f.) Brenan	Fl.Gab.	4B	1
Pseudoprosopis gilletii (De Wild.) Villiers	Fl.Gab.	2B	9
Tetrapleura tetraptera (Schum. & Thonn.) Taub.	Fl.Gab.	5	1

Orchidaceae (28 species)	Reference	Biodiversity category	Biodiversity value
Ancistrorhynchus capitatus (Lindl.) Summerh.	Fl.Afr.Centr.	4B	1
Ancistrorhynchus recurvus Finet	Fl.Afr.Centr.	4A	3
Angraecum podochiloides Schltr.	Fl.Afr.Centr.	4B	1
Bulbophyllum intertextum Lindl.	Fl.Afr.Centr.	5	1
Bulbophyllum ivorense Cribb & Perez-Vera	Fl.Afr.Centr.	4A	3
Bulbophyllum oreonastes Rchb.f.	Fl.Afr.Centr.	5	1
Bulbophyllum pumilum (Sw.) Lindl.	Fl.Afr.Centr.	4B	1
Bulbophyllum saltatorium Lindl.	Fl.Afr.Centr.	4B	1
Calyptrochilum christyanum (Rchb.f.) Summerh.	Fl.Afr.Centr.	5	1
Chamaeangis ichneumonea (Lindl.) Schltr.	FWTA	3B	3
Cynorkis debilis (Hook.f.) Summerh.	Fl.Afr.Centr.; Fl.Cam.	4B	1
Cyrtorchis ringens (Rchb.f.) Summerh.	Fl.Afr.Centr.	5	1
Diaphananthe bidens (Sw.) Schltr.	Fl.Afr.Centr.	4B	1
Diaphananthe rutila (Rchb.f.) Summerh.	Fl.Afr.Centr.	5	1
Eulophia euglossa Rchb.f.	Fl.Afr.Centr.	4B	1
Habenaria stenochila Lindl.	Fl.Cam.	2A	27
Liparis tridens Kraenzl.	FWTA; FTEA	4A	3
Listrostachys pertusa (Lindl.) Rchb.f.	FWTA	3B	3
Manniella gustavii Rchb.f.	Fl.Afr.Centr.	5	1
Microcoelia microglossa Summerh.	Fl.Afr.Centr.	3B	3
Polystachya concreta (Jacq.) Garey & Sweet	Fl.Afr.Centr.	5	1
Polystachya paniculata (Sw.) Rolfe	Fl.Afr.Centr.	4B	1
Polystachya polychaete Kraenzl.	FTEA	5	1

Orchidaceae (continued)	Reference	Biodiversity category	Biodiversity value
Polystachya seticaulis Rendle	Fl.Afr.Centr.	3B	3
Summerhaysia laurentii (De Wild.) Cribb	Fl.Afr.Centr.; FWTA	4A	3
Tridactyle anthomaniaca (Rchb.f.) Summerh.	Fl.Afr.Centr.	5	1
Zeuxine elongata Rolfe	Fl.Afr.Centr.	5	1
Zeuxine occidentalis (Summerh.) Geerinck	Fl.Afr.Centr.	4B	1

LITERATURE CITED FOR APPENDIX B

ARENDS, J. C. 1992. Studies in Begoniaceae IV. Biosystematics of *Begonia squamulosa* Hook. f. and affiliated species in section *Tetraphila* A.DC. Wageningen Agric. Univ. Papers 91–6:1–222.

BEENTJE, H. J. 1978. A revision of *Callichilia* Stapf (Apocynaceae). Meded. Landbouwhogeschool Wageningen 78–7:1–32.

BRETELER, F. J. 1978. The African Dichapetalaceae IV. Meded. Landbouwhogeschool Wageningen 78–10:1–84.

———. 1979. The African Dichapetalaceae V. Meded. Landbouwhogeschool Wageningen 79–16:1–78.

———. 1981. The African Dichapetalaceae VII. Meded. Landbouwhogeschool Wageningen 81–10:1–94.

———. 1982. The African Dichapetalaceae VIII. Meded. Landbouwhogeschool Wageningen 82–8:1–92.

———. 1986. The African Dichapetalaceae IX. Agric. Univ. Wageningen Papers 86–3:1–74.

———. 1993. Le genre *Dialium* (Caesalp.) au Gabon. Msc., Herbarium Vadense, Wageningen. 7 pp.

CHAMPLUVIER, D. 1991. Révision des genres *Staurogyne* Wall., *Anisosepalum* E.Hossain et *Saintpauliopsis* Staner (Acanthaceae) en Afrique tropicale. Bull. Jard. Bot. Nat. Belg. 61:93–159.

DILST, F. J. H. van AND A. J. M. LEEUWENBERG 1991. *Rauvolfia* L. in Africa and Madagascar. Series of revisions of Apocynaceae XXXIII. Bull. Jard. Bot. Nat. Belg. 61:21–69.

GREY-WILSON, C. 1980. *Impatiens* of Africa. A. A. Balkema, Rotterdam, the Netherlands. 235 pp.

HAEGENS, R. M. A. P. 1994. Revision of *Cylindropsis* Pierre and *Vahadenia* Stapf. Series of revisions of Apocynaceae XXXV. Bull. Jard. Bot. Nat. Belg. 63:313–328.

HALLÉ, N. AND A. M. LOUIS. 1989. Un nouvel *Impatiens* (Balsaminaceae) du Gabon. Bull. Mus. natn. Hist. nat., Paris, 4e sér., 11, sect. B, Adansonia:11–15.

HEINE, H. 1966. Révision du genre *Thomandersia* Baill. (Acanthaceae). Bull. Jard. Bot. Etat, Brux. 36:207–248.

HOOGH, B. DE 1989. *Dictyophleba* Pierre. Series of revisions of Apocynaceae XXVIII. Bull. Jard. Bot. Nat. Belg. 59:207–226.

JACQUES-FÉLIX, H. 1976. Le genre *Cincinnobotrys* Gilg (Mélastomatacées). Adansonia, sér. 2, 16:355–377.

———. 1979. Espèces nouvelles et peu connues du genre *Memecylon* (Melastomataceae) en Afrique. Adansonia, sér. 2, 18:409–432.

———. 1981. Révision du genre *Calvoa* (Melastomataceae). Bull. Mus. Natn. Hist. nat., Paris, 4e sér., 3, sect. B. Adansonia:123–143.

———. 1986. Description d'un *Tristemma* (Melastomataceae) nouveau du Gabon. Bull. Mus. Natn. Hist. Nat., Paris, 4e sér., 8, sect. B, Adansonia:191–193.

JONGKIND, C. C. H. 1995. Review of the genus *Strephonema* (Combretaceae). Ann. Missouri Bot. Gard. 82:535–541.

JONGKIND, C. C. H. AND R. H. M. J. LEMMENS. 1989. The Connaraceae, a taxonomic study with special emphasis on Africa. Thesis, Wageningen Agricultural University, the Netherlands. 403 pp.

KRUIF, A. P. M. DE 1981. A revision of *Holarrhena* R. Br. (Apocynaceae). Meded. Landbouwhogeschool Wageningen 81–2:1–40.

LEEUWENBERG, A. J. M. 1991. A revision of *Tabernaemontana* 1. The Old World species. Royal Botanic Gardens, Kew, Angleterre. xii + 211 pp.

————. 1995. Series of revisions of Apocynaceae, XL: Calocrater and Crioceras. Fontqueria 42:11–16.

MORTON, J. K. 1979. An overlooked species of *Nelsonia* (Acanthaceae) from Africa. Kew Bull. 33:399–402.

OMINO, E. 1996. A contribution to the leaf anatomy and taxonomy of Apocynaceae in Africa. Wageningen Agric. Univ. Papers 96–1:1–178.

PERSOON, J. G. M. et al. 1992. The African species of *Landolphia* P. Beauv. Series of revisions of Apocynaceae XXXIV. Wageningen Agric. Univ. Papers 92–2:1–232.

PLOEG, J. VAN DER 1985. Revision of the genera *Cyclocotyla* Stapf, *Dewevrella* De Wild. and of the African species of the genus *Malouetia* A.DC. (Apocynaceae). Series of revisions of Apocynaceae XVIII. Agric. Univ. Wageningen Papers 85–2:57–83.

ROJO, J. P. 1982. Studies in the genus *Dialium* (Cassieae-Caesalpinioideae). Thesis, Univ. Oxford. 282 pp.

SOSEF, M. S. M. 1994. Refuge begonias. Taxonomy, phylogeny and historical biogeography of *Begonia* sect. *Loasibegonia* and sect. *Scutobegonia* in relation to glacial rain forest refuges in Afica. Wageningen Agric. Univ. Papers 94–1:1–306.

VILLIERS, J. F. 1984. Le genre *Calpocalyx* (Leguminosae, Mimosoideae) en Afrique. Bull. Mus. natl. Hist. nat., Paris, sér. 4, 6, sect. B, Adansonia:297–311.

————. 1990. Contribution à l'étude du genre *Newtonia* Baillon (Leguminosae-Mimosoideae) en Afrique. Bull. Jard. Bot. Natl. Belgique 60:119–138.

VOLLESEN, K. 1992. The Old World species of *Stenandrium* (Acanthaceae: Acantheae). Kew Bull. 47:169–202.

VONK, G. J. A. 1989. A taxonomic revision of the genus *Orthopichonia*. Series of revisions of Apocynaceae XXX. Wageningen Agric. Univ. Papers 89-4:27–50.

VONK, G. J. A. AND A. J. M. LEEUWENBERG, 1989. A taxonomic revision of the genus *Tabernanthe* and a study of the wood anatomy of *T. iboga*. Series of revisions of Apocynaceae XXIX. Wageningen Agric. Univ. Papers 89–4:1–18.

WIERINGA, J. J. 1999. Monopetalanthus exit. A systematic study of *Aphanocalyx, Bikinia, Icuria, Michelsonia* and *Tetraberlinia* (Leguminosae, Caesalpinioideae). Wageningen Agric. Univ. Papers 99–4:1–320.

————. ms. A taxonomic revision of *Begonia* section *Filicibegonia* A.DC. Ms Wageningen Agricultural University. 44 pp.

WILDE, J. J. F. E. DE. 2002. Begonia section *Tetraphila* A.DC., a taxonomic revision. Studies in Begoniaceae VII. Wageningen Univ. Papers 2001–2: 6–258.

WILDE, J. J. F. E. DE AND J. C. ARENDS. 1979. *Begonia loranthoides* Hook. f. (sect. Tetraphila A.DC.). Acta Bot. Neerl. 28:357–374.

APPENDIX C

PLOT DATA

Plot 1: March 23, 2000; 2°17'S, 10°30'E; alt. 100 m; terrain flat, well-drained; canopy at ± 40 m, with *Celtis, Cylicodiscus, Dialium, Plagiostyles* and *Staudtia*; sub-canopy dominated by *Cola flavovelutina* and *Meiocarpidium lepidotum*; understory open.

Species (22)	Family (16)	Number of stems (64)
Annickia chlorantha	Annonaceae	1
Meiocarpidium lepidotum	Annonaceae	18
Xylopia hypolampra	Annonaceae	1
Picralima nitida	Apocynaceae	1
Dacryodes edulis	Burseraceae	1
Dialium angolense	Caesalpiniaceae	3
Diospyros dendo	Ebenaceae	2
Diospyros fragrans	Ebenaceae	1
Diospyros piscatoria	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	3

Plagiostyles africana	Euphorbiaceae	3
Trichilia sp. 1	Meliaceae	1
Calpocalyx dinklagei	Mimosaceae	2
Cylicodiscus gabonensis	Mimosaceae	1
Staudtia kamerunensis	Myristicaceae	4
Coula edulis	Olacaceae	3
Schumanniophyton hirsutum	Rubiaceae	1
Zanthoxylum gilletii	Rutaceae	1
Gambeya africana	Sapotaceae	1
Cola flavovelutina	Sterculiaceae	11
Grewia coriacea	Tiliaceae	1
Celtis tessmannii	Ulmaceae	3

Plot 2: March 24, 2000; 2°17′S, 10°30′E; alt. 100 m; terrain flat, swampy; canopy at ± 45 m, with *Berlinia bracteosa, Calpocalyx heitzii, Hallea ledermannii* and *Sterculia tragacantha*; sub-canopy dominated by *Anthonotha macrophylla, Diospyros physocalycina* and three species of *Cola*; understory open.

Species (30)	Family (11)	Number of stems (106)
Meiocarpidium lepidotum	Annonaceae	1
Uvariastrum pierreanum	Annonaceae	3
Anthonotha macrophylla	Caesalpiniaceae	22
Berlinia bracteosa	Caesalpiniaceae	4
Dialium angolense	Caesalpiniaceae	2
Didelotia africana	Caesalpiniaceae	3
Gilbertiodendron unijugum	Caesalpiniaceae	3
Diospyros gabunensis	Ebenaceae	1
Diospyros iturensis	Ebenaceae	1
Diospyros physocalycina	Ebenaceae	15
Diospyros sp. 1	Ebenaceae	2
Drypetes ituriensis (cf.)	Euphorbiaceae	1
Drypetes molunduana (cf.)	Euphorbiaceae	1
Mareya micrantha	Euphorbiaceae	1
Homalium letestui	Flacourtiaceae	1
Oncoba glauca	Flacourtiaceae	1
Anthocleista vogelii	Loganiaceae	2
Carapa procera	Meliaceae	3
Khaya ivorensis	Meliaceae	1
Trichilia monodelpha	Meliaceae	2
Trichilia prieureana	Meliaceae	3
Calpocalyx dinklagei	Mimosaceae	12
Calpocalyx heitzii	Mimosaceae	2
Baphia leptostemma (cf.)	Papilonaceae	1
Hallea ledermannii	Rubiaceae	4
Heinsia crinita	Rubiaceae	1
Cola flavovelutina	Sterculiaceae	3
Cola griseiflora (cf.)	Sterculiaceae	3
Cola lateritia	Sterculiaceae	5
Sterculia tragacantha	Sterculiaceae	2

Plot 3: March 25, 2000; 2°14′S, 10°27′E; alt. 150 m; terrain with slight inclination, well-drained soil; canopy at ± 35 m, with *Parkia filicoidea, Petersianthus macrocarpus*

and *Staudtia gabonensis*; sub-canopy with abundance of *Dichostemma glaucescens* and *Diospyros* spp.; understory open.

Species (27)	Family (13)	Number of stems (97)
Greenwayodendron suaveolens	Annonaceae	1
Meiocarpidium lepidotum	Annonaceae	6
Crudia sp. 1	Caesalpiniaceae	1
Cynometra lujae (cf.)	Caesalpiniaceae	3
Dialium angolense	Caesalpiniaceae	1
Neochevalierodendron stephanii	Caesalpiniaceae	1
Diospyros fragrans	Ebenaceae	1
Diospyros iturensis	Ebenaceae	7
Diospyros mannii	Ebenaceae	2
Diospyros obliquifolia	Ebenaceae	2
Diospyros zenkeri	Ebenaceae	2
Diospyros sp. 2	Ebenaceae	4
Centroplacus glaucinus	Euphorbiaceae	1
Dichostemma glaucescens	Euphorbiaceae	43
Maprounea membranacea	Euphorbiaceae	1
Desbordesia glaucescens	Irvingiaceae	2
Petersianthus macrocarpus	Lecythidaceae	1
Trichilia sp. 1	Meliaceae	1
Parkia filicoidea	Mimosaceae	1
Pycnanthus angolensis	Myristicaceae	3
Staudtia kamerunensis	Myristicaceae	2
Coula edulis	Olacaceae	3
Diogoa zenkeri	Olacaceae	2
Pausinystalia macroceras	Rubiaceae	1
Tricalysia biafrana (cf.)	Rubiaceae	1
Chytranthus sp. 1	Sapindaceae	3
Cola griseiflora (cf.)	Sterculiaceae	1

Plot 4: March 27, 2000; 2°17.6'S, 10°30.3'E; alt. 150 m; terrain almost flat, slight inclination in one corner, well-drained soil; canopy at 35–40 m, with *Celtis tessmannii, Pentaclethra eetveldiana, Pterocarpus soyauxii* and *Scorodophloeus zenkeri*; sub-canopy dominated by several *Diospyros* species, *Nesogordonia papaverifera* and *Diogoa zenkeri*; understory open.

Species (27)	Family (16)	Number of stems (76)
Thomandersia sp. 1	Acanthaceae	4
Meiocarpidium lepidotum	Annonaceae	2
Uvariastrum pierreanum	Annonaceae	2
Dacryodes letestui	Burseraceae	1
Anthonotha sp. 1	Caesalpiniaceae	1
Berlinia confusa	Caesalpiniaceae	1
Cynometra nyangensis (cf.)	Caesalpiniaceae	1
Dialium angolense	Caesalpiniaceae	1
Scorodophloeus zenkeri	Caesalpiniaceae	4
Diospyros dendo	Ebenaceae	14
Diospyros fragrans	Ebenaceae	1
Diospyros hoyleana	Ebenaceae	3
Diospyros iturensis	Ebenaceae	13

Discoglypremna caloneura	Euphorbiaceae	1
Drypetes ituriensis (cf.)	Euphorbiaceae	1
Plagiostyles africana	Euphorbiaceae	1
Trichilia prieureana	Meliaceae	1
Pentaclethra eetveldeana	Mimosaceae	2
Staudtia kamerunensis	Myristicaceae	1
Diogoa zenkeri	Olacaceae	5
Pterocarpus soyauxii	Papilonaceae	2
Pausinystalia macroceras	Rubiaceae	3
Schumanniophyton hirsutum	Rubiaceae	1
Chytranthus sp. 1	Sapindaceae	1
Synsepalum longecuneatum	Sapotaceae	2
Nesogordonia papaverifera	Sterculiaceae	6
Celtis tessmannii	Ulmaceae	1

Plot 5 : April 7, 2000; 2°13′S, 10°24′E; alt. 380 m; terrain with inclination of ± 10° towards the east, well-drained soil; canopy at ± 40 m, with *Bikinia le-testui, Marquesia excelsa* and *Plagiosiphon emarginatus;* subcanopy without any distinct dominance; understory open.

Species (35)	Family (16)	Number of stems (78)
Trichoscypha acuminata	Anacardiaceae	1
Anisophyllea myriosticta	Anisophylleaceae	1
Anisophyllea polyneura	Anisophylleaceae	2
Anonidium mannii	Annonaceae	2
Uvariastrum pierreanum	Annonaceae	3
Dacryodes buettneri	Burseraceae	1
Santiria trimera	Burseraceae	6
Bikinia le-testui	Caesalpiniaceae	4
Dialium angolense	Caesalpiniaceae	1
Dialium guineense	Caesalpiniaceae	2
Plagiosiphon emarginatus	Caesalpiniaceae	7
Marquesia excelsa	Dipterocarpaceae	3
Diospyros melocarpa	Ebenaceae	4
Cleistanthus sp. 1	Euphorbiaceae	4
Cleistanthus sp. 2	Euphorbiaceae	2
Dichostemma glaucescens	Euphorbiaceae	1
Drypetes sp. 1	Euphorbiaceae	5
Klaineanthus gaboniae	Euphorbiaceae	6
Maprounea membranacea	Euphorbiaceae	1
Maprounea sp. 1	Euphorbiaceae	2
Carapa procera	Meliaceae	1
Coula edulis	Olacaceae	2
Diogoa zenkeri	Olacaceae	1
Heisteria zimmereri	Olacaceae	1
Strombosiopsis tetrandra	Olacaceae	1
Dactyladenia barteri	Rosaceae	1
Pausinystalia johimbe	Rubiaceae	1
Pausinystalia macroceras	Rubiaceae	1
Pausinystalia sp. 1	Rubiaceae	2
Deinbollia sp. 1	Sapindaceae	1
Eriocoelum sp. 1	Sapindaceae	1
Pancovia floribunda	Sapindaceae	3
Manilkara fouilloyana	Sapotaceae	1

Oubanguia africana	Scytopetalaceae	2
Cola rostrata	Sterculiaceae	1

Plot 6 : April 8, 2000; 2°13′S, 10°24′E; alt. 460 m; forest on ridge with steep slopes on either side; canopy at ± 30 m; abundance of *Dacryodes* spp., *Garcinia* spp., *Ochtocosmus calothyrsus* and *Santiria trimera*; understory fairly dense.

Species (41)	Family (21)	Number of stems (106)
Trichoscypha sp. 1	Anacardiaceae	1
Anonidium mannii	Annonaceae	1
Greenwayodendron suaveolens	Annonaceae	1
Xylopia sp. 1	Annonaceae	1
Aucoumea klaineana	Burseraceae	1
Dacryodes buettneri	Burseraceae	1
Dacryodes edulis	Burseraceae	1
Dacryodes igaganga	Burseraceae	5
Dacryodes klaineana	Burseraceae	2
Santiria trimera	Burseraceae	18
Daniellia klainei	Caesalpiniaceae	1
Dialium angolense	Caesalpiniaceae	2
Plagiosiphon emarginatus	Caesalpiniaceae	4
Tapura letestui	Dichapetalaceae	1
Diospyros melocarpa	Ebenaceae	4
Centroplacus glaucinus	Euphorbiaceae	4
Cleistanthus sp. 2	Euphorbiaceae	2
Cleistanthus sp. 3	Euphorbiaceae	1
Dichostemma glaucescens	Euphorbiaceae	3
Maesobotrya sp. 1	Euphorbiaceae	1
Maprounea membranacea	Euphorbiaceae	1
Homalium sp. 1	Flacourtiaceae	1
Garcinia conrauana	Guttiferae	2
Garcinia lucida	Guttiferae	7
Garcinia smeathmannii	Guttiferae	1
Ochtocosmus calothyrsus	Ixonanthaceae	6
Beilschmiedia dinklagei	Lauraceae	2
Warneckea sp. 1	Melastomataceae	1
Newtonia griffoniana	Mimosaceae	1
Lophira alata	Ochnaceae	1
Coula edulis	Olacaceae	1
Strombosia sp. 1	Olacaceae	2
Strombosiopsis tetrandra	Olacaceae	2
Pausinystalia johimbe	Rubiaceae	3
Rothmannia longiflora (cf.)	Rubiaceae	1
Rothmannia sp. 1	Rubiaceae	1
Zanthoxylum gilletii	Rutaceae	1
Pancovia floribunda	Sapindaceae	2
Manilkara fouilloyana	Sapotaceae	2
Scytopetalum klaineanum	Scytopetalaceae	1
Odyendyea gabonensis	Simaroubaceae	2

Plot 7: April 9, 2000; 2°14′S, 10°24′E; alt. 650 m; terrain sloping with 6–8° to the East, well-drained; canopy at ± 35 m; sub-canopy without any distinct dominant species; understory well-developed.

Species (40)	Family (20)	Number of stems (113)
Anisophyllea purpurascens	Anisophylleaceae	4
Anisophyllea purpurascens (cf.)	Anisophylleaceae	1
Anonidium mannii	Annonaceae	5
Anonidium sp. 1	Annonaceae	2
Xylopia sp. 1	Annonaceae	1
Xylopia staudtii	Annonaceae	2
Xylopia sp. 1	Apocynaceae	1
Dacryodes edulis	Burseraceae	1
Dacryodes sp. 1	Burseraceae	1
Santiria trimera	Burseraceae	6
Anthonotha ferruginea	Caesalpiniaceae	1
Baikiaea insignis	Caesalpiniaceae	3
Gilbertiodendron unijugum	Caesalpiniaceae	6
Scorodophloeus zenkeri	Caesalpiniaceae	4
Hemandradenia mannii	Connaraceae	1
Diospyros hoyleana	Ebenaceae	1
Diospyros melocarpa	Ebenaceae	4
Croton sylvaticus	Euphorbiaceae	1
Dichostemma glaucescens	Euphorbiaceae	5
Drypetes gilgiana	Euphorbiaceae	5
Klaineanthus gaboniae	Euphorbiaceae	3
Garcinia conrauana	Guttiferae	7
Garcinia smeathmannii	Guttiferae	13
Afrostyrax kamerunensis	Huaceae	1
Ochtocosmus calothyrsus	Ixonanthaceae	3
Beilschmiedia dinklagei	Lauraceae	1
Warneckea sp. 2	Melastomataceae	4
Calpocalyx dinklagei	Mimosaceae	3
Newtonia leucocarpa	Mimosaceae	2
Eugenia sp. 1	Myrtaceae	1
Strombosia scheffleri	Olacaceae	6
Strombosiopsis tetrandra	Olacaceae	6
Dactyladenia sp. 1	Rosaceae	1
Rothmannia longifolia (cf.)	Rubiaceae	1
Rothmannia sp. 2	Rubiaceae	1
Eriocoelum sp. 2	Sapindaceae	1
Chrysophyllum sp. 1	Sapotaceae	1
Letestua durissima	Sapotaceae	1
Zeyherella letestui	Sapotaceae	1
Zeyherella mayombense	Sapotaceae	1

Plot 8: April 10, 2000; 2°13′S, 10°24′E; alt. 350 m; terrain sloping ± 10° to the northeast, well-drained; canopy at ± 40 m; sub-canopy without any distinct dominant species; understory well-developed.

Species (35)	Family (16)	Number of stems (80)
Anisophyllea purpurascens	Anisophylleaceae	1

Anonidium mannii	Annonaceae	6
Greenwayodendron suaveolens	Annonaceae	2
Greenwayodendron sp. 2	Annonaceae	1
Uvariastrum pierreanum	Annonaceae	1
Dacryodes edulis	Burseraceae	2
Dacryodes klaineana	Burseraceae	1
Santiria trimera	Burseraceae	9
Berlinia sp. 1	Caesalpiniaceae	1
Copaifera religiosa	Caesalpiniaceae	1
Dialium guineense	Caesalpiniaceae	3
Gilbertiodendron sp. 1	Caesalpiniaceae	1
Tetraberlinia polyphylla	Caesalpiniaceae	2
Diospyros cinnabarina	Ebenaceae	3
Diospyros zenkeri	Ebenaceae	1
Cyrtogonone argentea	Euphorbiaceae	1
Dichostemma glaucescens	Euphorbiaceae	6
Drypetes sp. 1	Euphorbiaceae	1
Plagiostyles africana	Euphorbiaceae	1
Scottellia klaineana	Flacourtiaceae	2
Klainedoxa gabonensis	Irvingiaceae	1
Guarea thompsonii	Meliaceae	1
Syzygium staudtii (cf.)	Myrtaceae	1
Coula edulis	Olacaceae	5
Diogoa zenkeri	Olacaceae	7
Heisteria zimmereri	Olacaceae	5
Strombosia pustulata	Olacaceae	1
Strombosia scheffleri	Olacaceae	2
Strombosiopsis tetrandra	Olacaceae	1
Magnistipula sp. 1	Rosaceae	1
Corynanthe mayumbensis	Rubiaceae	1
Araliopsis soyauxii	Rutaceae	1
Pancovia floribunda	Sapindaceae	2
Pancovia sp. 1	Sapindaceae	4
Scytopetalum sp. 1	Scytopetalaceae	1

Plot 9: May 14, 2000; 2°27.6′S, 10°32.5′E; alt. 195 m; level, rocky terrain, well-drained; canopy at ± 40 m; sub-canopy with abundance of *Dichostemma glaucescens*; understory dense.

Species (17)	Family (13)	Number of stems (51)
Sorindeia sp. 1	Anacardiaceae	1
Dacryodes sp. 2	Burseraceae	1
Cynometra sp. 1	Caesalpiniaceae	1
Gilbertiodendron brachystegioides	Caesalpiniaceae	1
Diospyros fragrans	Ebenaceae	4
Dichostemma glaucescens	Euphorbiaceae	22
Scottellia klaineana	Flacourtiaceae	1
Trichilia prieureana	Meliaceae	1
Pentaclethra eetveldeana	Mimosaceae	1
Staudtia kamerunensis	Myristicaceae	5
Pinacopodium congolense	Nectaropetaceae	3
Coula edulis	Olacaceae	1
Diogoa zenkeri	Olacaceae	4
Strombosia pustulata	Olacaceae	2

Ximenia americana ?	Olacaceae	1
Maranthes glabra	Rosaceae	1
Pancovia floribunda	Sapindaceae	1

Plot 10: May 15, 2000; 2°27.4′S, 10°32.0′E; alt. 535 m; top of a ridge; canopy at ± 35 m; sub-canopy with abundance of *Santiria trimera*; understory open.

Species (32)	Family (17)	Number of stems (89)
Anisophyllea purpurascens	Anisophylleaceae	2
Anonidium mannii	Annonaceae	1
Greenwayodendron suaveolens	Annonaceae	1
Greenwayodendron sp. 3	Annonaceae	2
Dacryodes klaineana	Burseraceae	4
Santiria trimera	Burseraceae	20
Anthonotha ferruginea	Caesalpiniaceae	5
Aphanocalyx heitzii	Caesalpiniaceae	1
Dialium angolense	Caesalpiniaceae	2
Scorodophloeus zenkeri	Caesalpiniaceae	1
Diospyros fragrans	Ebenaceae	1
Diospyros hoyleana	Ebenaceae	5
Diospyros melocarpa	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	2
Plagiostyles africana	Euphorbiaceae	1
Uapaca staudtii (cf.)	Euphorbiaceae	1
Homalium sp. 2	Flacourtiaceae	5
Scottellia klaineana	Flacourtiaceae	1
Garcinia conrauana	Guttiferae	1
Ochtocosmus calothyrsus	Ixonanthaceae	3
Beilschmiedia sp. 1	Lauraceae	3
Warneckea floribunda (cf.)	Melastomataceae	8
Calpocalyx sp. 1	Mimosaceae	6
Fillaeopsis discophora	Mimosaceae	1
Newtonia leucocarpa	Mimosaceae	1
Strombosia pustulata	Olacaceae	1
Strombosiopsis tetrandra	Olacaceae	3
Dactyladenia sp. 2	Rosaceae	1
Maranthes glabra	Rosaceae	2
Oubanguia africana	Scytopetalaceae	1
Odyendyea gabonensis	Simaroubaceae	1
Nesogordonia sp. 1	Sterculiaceae	1

Plot 11: May 16, 2000; alt. 430 m; terrain on a ± 8° slope, well-drained soil; canopy at ± 40 m; sub-canopy with dominance of *Dichostemma glaucescens, Diospyros* spp. and *Maprounea membranacea*; understory fairly dense.

Species (26)	Family (14)	Number of stems (107)
Sorindeia grandifolia (cf)	Anacardiaceae	3
Greenwayodendron suaveolens	Annonaceae	3
Xylopia aethiopica	Annonaceae	3
Xylopia sp. 2	Annonaceae	1
Hunteria umbellata	Apocynaceae	4
Dacryodes buettneri	Burseraceae	1

Dacryodes klaineana	Burseraceae	1
Santiria trimera	Burseraceae	5
Dialium angolense	Caesalpiniaceae	3
Dialium dinklagei	Caesalpiniaceae	1
Librevillea klainei	Caesalpiniaceae	6
Diospyros fragrans	Ebenaceae	7
Diospyros hoyleana	Ebenaceae	10
Diospyros melocarpa	Ebenaceae	5
Dichostemma glaucescens	Euphorbiaceae	20
Klaineanthus gaboniae	Euphorbiaceae	1
Maprounea membranacea	Euphorbiaceae	14
Homalium sp. 2	Flacourtiaceae	1
Newtonia leucocarpa	Mimosaceae	1
Strombosia pustulata	Olacaceae	2
Dactyladenia barteri	Rosaceae	3
Dactyladenia sp. 3	Rosaceae	1
Dactyladenia sp. 1	Rubiaceae	5
Pancovia floribunda	Sapindaceae	4
Pancovia sp. 2	Sapindaceae	1
Zeyherella letestui	Sapotaceae	1

Plot 12: May 17, 2000; 2°28′S, 10°32′E; alt. 145 m; terrain slightly sloping, well-drained soil; canopy at ± 50 m; sub-canopy without obvious dominance; understory fairly dense with dominance of an *Ixora* sp. and *Phyllanthus diandrus*.

Species (29)	Family (14)	Number of stems (52)
Thomandersia hensii	Acanthaceae	4
Sorindeia sp. 2	Anacardiaceae	1
Trichoscypha acuminata	Anacardiaceae	2
Dacryodes edulis	Burseraceae	1
Dacryodes sp. 3	Burseraceae	1
Santiria trimera	Burseraceae	4
Cynometra sp. 2	Caesalpiniaceae	2
Dialium angolense	Caesalpiniaceae	2
Dialium dinklagei	Caesalpiniaceae	1
Distemonanthus benthamianus	Caesalpiniaceae	1
Diospyros fragrans	Ebenaceae	1
Diospyros sp. 3	Ebenaceae	2
Margaritaria discoideus	Euphorbiaceae	1
Plagiostyles africana	Euphorbiaceae	2
Uapaca guineensis	Euphorbiaceae	1
Garcinia sp. 1	Guttiferae	1
Desbordesia glaucescens	Irvingiaceae	1
Irvingia gabonensis	Irvingiaceae	1
Parkia bicolor	Mimosaceae	1
Coula edulis	Olacaceae	9
Diogoa zenkeri	Olacaceae	2
Heisteria zimmereri	Olacaceae	4
Strombosiopsis tetrandra	Olacaceae	1
Angylocalyx sp. 1	Papilionaceae	1
Pausinystalia macroceras	Rubiaceae	1
Chytranthus sp. 2	Sapindaceae	1
Ganophyllum giganteum	Sapindaceae	1
Pancovia floribunda	Sapindaceae	1

Vitex gabonensis (cf)	Verbenaceae	1

Plot 13: May 18, 2000; 2°27.6'S, 10°32.5'E; alt. 265 m; terrain level, well-drained; canopy at ± 45 m; sub-canopy dominated by *Dichostemma glaucescens*; understory fairly dense with dominance of *Coula edulis, Diospyros obliquifolia, Dichostemma glaucescens, Strombosia pustulata* and *Entada gigas.*

Species (27)	Family (16)	Number of stems (103)
Thomandersia hensii	Acanthaceae	1
Sorindeia sp. 1	Anacardiaceae	1
Trichoscypha acuminata	Anacardiaceae	1
Isolona campanulata	Annonaceae	1
Dacryodes edulis	Burseraceae	4
Dacryodes klaineana	Burseraceae	2
Santiria trimera	Burseraceae	2
Bobgunnia fistuloides	Caesalpiniaceae	1
Cynometra sp. 2	Caesalpiniaceae	5
Dialium angolense	Caesalpiniaceae	3
Guibourtia tessmannii	Caesalpiniaceae	1
Diospyros fragrans	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	52
Scottellia klaineana	Flacourtiaceae	2
Desbordesia glaucescens	Irvingiaceae	2
Beilschmiedia oblongifolia (cf)	Lauraceae	1
Pentaclethra eetveldeana	Mimosaceae	2
Staudtia kamerunensis	Myristicaceae	1
Coula edulis	Olacaceae	3
Diogoa zenkeri	Olacaceae	4
Strombosia pustulata	Olacaceae	1
Strombosia scheffleri	Olacaceae	1
Maranthes glabra	Rosaceae	1
Ganophyllum giganteum	Sapindaceae	1
Pancovia floribunda	Sapindaceae	6
Chrysophyllum subnudum	Sapotaceae	2
Gambeya africana	Sapotaceae	1

Plot 14: May 19, 2000; 2°28.0'S, 10°32.5'E; alt. 150 m; terrain level, swampy soil; canopy at ± 25 m; understory fairly dense, dominated by *Greenwayodendron suaveolens, Salacia* sp., *Thomandersia hensii* and *Tricalysia* sp. 1.

Species (39)	Family (22)	Number of stems (71)
Thomandersia hensii	Acanthaceae	2
Lannea welwitschii	Anacardiaceae	1
Pseudospondias longifolia	Anacardiaceae	1
Xylopia quintasii	Annonaceae	1
Newbouldia laevis	Bignoniaceae	1
Dacryodes igaganga	Burseraceae	1
Dialium dinklagei	Caesalpiniaceae	1
Diospyros dendo	Ebenaceae	3
Diospyros mannii	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	1
Margaritaria discoideus	Euphorbiaceae	2

Uapaca guineensis	Euphorbiaceae	1
Lasianthera africana	Icacinaceae	1
Desbordesia glaucescens	Irvingiaceae	2
Irvingia gabonensis	Irvingiaceae	3
Irvingia grandifolia	Irvingiaceae	2
Carapa procera	Meliaceae	1
Trichilia prieureana	Meliaceae	1
Pentaclethra eetveldeana	Mimosaceae	4
Pentaclethra macrophylla	Mimosaceae	1
Myrianthus arboreus	Moraceae	1
Coula edulis	Olacaceae	1
Diogoa zenkeri	Olacaceae	9
Heisteria zimmereri	Olacaceae	1
Strombosia grandifolia	Olacaceae	5
Strombosia pustulata	Olacaceae	1
Ximenia americana	Olacaceae	1
Pterocarpus soyauxii	Papilonaceae	1
Barteria fistulosa	Passifloraceae	1
Maranthes glabra	Rosaceae	1
Aoranthe cladantha	Rubiaceae	1
Pausinystalia macroceras	Rubiaceae	1
Pausinystalia sp. 3	Rubiaceae	1
Tricalysia sp. 1	Rubiaceae	6
Vangueropsis rubiginosa	Rubiaceae	1
Eriocoelum sp. 3	Sapindaceae	4
Gambeya africana	Sapotaceae	2
Scytopetalum klaineanum	Scytopetalaceae	1
Cola sp. 1	Sterculiaceae	1

Plot 15: May 29, 2000; 2°23.1'S, 10°30.7'E; alt. 545 m; forest on ridge, terrain slightly sloping, well-drained soil; canopy at ± 30 m, with *Aphanocalyx microphyllus* and *Odyendyea gabonensis* as large emergents; sub-canopy dominated by *Dichostemma glaucescens* and *Synsepalum longecuneatum*; understory fairly dense.

Species (40)	**Family (22)**	**Number of stems (104)**
Trichoscypha acuminata	Anacardiaceae	1
Trichoscypha sp. 2	Anacardiaceae	1
Trichoscypha sp. 3	Anacardiaceae	1
Anisophyllea polyneura	Anisophylleaceae	3
Anonidium mannii	Annonaceae	6
Isolona zenkeri	Annonaceae	1
Tabernaemontana crassa	Apocynaceae	1
Dacryodes klaineana	Burseraceae	1
Santiria trimera	Burseraceae	10
Anthonotha fragrans	Caesalpiniaceae	1
Aphanocalyx microphyllus	Caesalpiniaceae	4
Berlinia confusa	Caesalpiniaceae	1
Daniellia klainei	Caesalpiniaceae	1
Guibourtia ehie	Caesalpiniaceae	1
Strephonema sericeum	Combretaceae	1
Diospyros dendo	Ebenaceae	1
Diospyros melocarpa	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	17
Klaineanthus gabonie	Euphorbiaceae	1

Oncoba flagelliflora (cf)	Flacourtiaceae	1
Beilschmiedia sp. 1	Lauraceae	1
Beilschmiedia sp. 2	Lauraceae	6
Memecylon sp. 1	Melastomataceae	1
Warneckea sapinii	Melastomataceae	2
Carapa procera	Meliaceae	2
Guarea sp. 1	Meliaceae	1
Pentaclethra eetveldeana	Mimosaceae	1
Syzygium staudtii	Myrtaceae	1
Coula edulis	Olacaceae	3
Diogoa zenkeri	Olacaceae	2
Strombosia pustulata	Olacaceae	2
Strombosiopsis tetrandra	Olacaceae	3
Psychotria sp. 1	Rubiaceae	1
Psychotria sp. 4	Rubiaceae	1
Deinbollia sp. 2	Sapindaceae	2
Synsepalum longecuneatum	Sapotaceae	13
Odyendyea gabonensis	Simaroubaceae	4
Cola lateritia	Sterculiaceae	·1
Nesogordonia papaverifera	Sterculiaceae	1
Grewia coriacea	Tiliaceae	1

Plot 16: May 30, 2000; 2°24.4′S, 10°27.1′E; alt. 655 m; forest on hilltop, lots of mosses and epiphytes on trees, well-drained soil; canopy at 20–25 m, with *Eugenia* sp. 2, *Protomegabaria* sp. 1 and *Santiria trimera*; sub-canopy dominated by *Berlinia* sp. 2, *Dacryodes edu*lis and *Strombosiopsis tetrandra;* understory fairly dense.

Species (40)	Family (22)	Number of stems (114)
Sorindeia sp. 3	Anacardiaceae	1
Trichoscypha sp. 4	Anacardiaceae	4
Anisophyllea purpurascens	Anisophylleaceae	2
Hunteria umbellata	Apocynaceae	3
Hunteria sp. 2	Apocynaceae	3
Dacryodes edulis	Burseraceae	6
Dacryodes igaganga	Burseraceae	1
Dacryodes macrophylla (cf)	Burseraceae	1
Santiria trimera	Burseraceae	13
Anthonotha fragrans	Caesalpiniaceae	3
Berlinia sp. 2	Caesalpiniaceae	10
Dialium dinklagei	Caesalpiniaceae	4
Strephonema sericeum	Combretaceae	1
Hemandradenia mannii	Connaraceae	1
Diospyros piscatoria	Ebenaceae	1
Diospyros sp. 4	Ebenaceae	1
Drypetes ituriensis (cf)	Euphorbiaceae	1
Klaineanthus gaboniae	Euphorbiaceae	2
Maesobotrya sp. 2	Euphorbiaceae	1
Protomegabaria sp. 1	Euphorbiaceae	1
Uapaca guineensis	Euphorbiaceae	2
Oncoba sp. 1	Flacourtiaceae	9
Garcinia smeathmannii	Guttiferae	2
Beilschmiedia sp. 3	Lauraceae	1
Beilschmiedia sp. 4	Lauraceae	1
Memecylon sp. 2	Melastomataceae	1

Warneckea sapinii	Melastomataceae	1
Parkia bicolor	Mimosaceae	1
Eugenia sp. 2	Myrtaceae	9
Strombosia scheffleri	Olacaceae	4
Strombosiopsis tetrandra	Olacaceae	7
Barteria nigritana	Passifloraceae	1
Psychotria sp. 1	Rubiaceae	1
Tarenna lasiorachis	Rubiaceae	1
Tricalysia pallens	Rubiaceae	1
Pancovia sp. 2	Sapindaceae	2
Synsepalum longecuneatum	Sapotaceae	5
Vitex sp. 1	Verbenaceae	3
Decorsella paradoxa	Violaceae	2

Plot 17: June 1, 2000; 2°22.5′S, 10°29.8′E; alt. 225 m; terrain level, swampy; canopy at ± 35 m, with *Irvingia gabonensis, Pentaclethra eetveldeana* and *Strombosiopsis tetrandra*; sub-canopy dominated by *Diospyros dendo, Grewia coriacea* and *Strombosia grandifolia*; understory fairly dense, with lots of lianas.

Species (38)	Family (20)	Number of stems (88)
Thomandersia hensii	Acanthaceae	4
Sorindeia sp. 4	Anacardiaceae	1
Annickia chlorantha	Annonaceae	1
Greenwayodendron suaveolens	Annonaceae	1
Uvariastrum pierreanum	Annonaceae	1
Xylopia quintasii	Annonaceae	1
Santiria trimera	Burseraceae	2
Berlinia bracteosa	Caesalpiniaceae	1
Dialium angolense	Caesalpiniaceae	2
Dialium dinklagei	Caesalpiniaceae	2
Guibourtia ehie	Caesalpiniaceae	2
Dichapetalum sp. 1	Dichapetalaceae	1
Diospyros dendo	Ebenaceae	6
Diospyros sp. 5	Ebenaceae	1
Dichostemma glaucescens	Euphorbiaceae	11
Mareya micrantha	Euphorbiaceae	1
Uapaca heudelotii	Euphorbiaceae	1
Garcinia ovalifolia	Guttiferae	1
Irvingia gabonensis	Irvingiaceae	7
Klainedoxa gabonensis	Irvingiaceae	1
Petersianthus macrocarpus	Lecythidaceae	1
Trichilia prieureana	Meliaceae	1
Pentaclethra eetveldeana	Mimosaceae	2
Myrianthus serratus	Moraceae	1
Syzygium staudtii	Myrtaceae	1
Coula edulis	Olacaceae	2
Diogoa zenkeri	Olacaceae	4
Heisteria zimmereri	Olacaceae	2
Strombosia grandifolia	Olacaceae	4
Strombosia pustulata	Olacaceae	4
Strombosiopsis tetrandra	Olacaceae	4
Corynanthe mayombensis	Rubiaceae	1
Massularia acuminata	Rubiaceae	1
Pausinystalia macroceras	Rubiaceae	1

Psydrax arnoldiana	Rubiaceae	1
Placodiscus opacus	Sapindaceae	1
Cola altissima	Sterculiaceae	1
Grewia coriacea	Tiliaceae	12

Plot 18: June 2, 2000; 2°23.0′S, 10°29.5′E; alt. 230 m; terrain slightly sloping, well-drained soil; canopy at ± 40 m; sub-canopy dominated by *Dichostemma glaucescens* and *Strombosia pustulata;* understory open.

Species (30)	Family (15)	Number of stems (96)
Thomandersia hensii	Acanthaceae	2
Uvariastrum pierreanum	Annonaceae	1
Santiria trimera	Burseraceae	1
Dialium angolense	Caesalpiniaceae	1
Guibourtia ehie	Caesalpiniaceae	1
Hylodendron gabunense	Caesalpiniaceae	1
Diospyros dendo	Ebenaceae	6
Diospyros piscatoria	Ebenaceae	1
Centroplacus glaucinus	Euphorbiaceae	1
Dichostemma glaucescens	Euphorbiaceae	42
Plagiostyles africana	Euphorbiaceae	1
Hua gabonii	Huaceae	1
Desbordesia glaucescens	Irvingiaceae	1
Entandrophragma congolensis	Meliaceae	1
Trichilia prieureana	Meliaceae	3
Cylicodiscus gabonensis	Mimosaceae	1
Pentaclethra eetveldeana	Mimosaceae	1
Piptadeniastrum africanum	Mimosaceae	1
Coula edulis	Olacaceae	2
Strombosia pustulata	Olacaceae	12
Paropsiopsis	Passifloraceae	1
Pausinystalia johimbe	Rubiaceae	1
Pausinystalia macroceras	Rubiaceae	1
Rothmannia liebrechtsiana	Rubiaceae	2
Schumanniophyton hirsutum	Rubiaceae	1
Tarenna jolinonii	Rubiaceae	1
Chytranthus macrobotrys	Sapindaceae	1
Chytranthus talbotii	Sapindaceae	1
Placodiscus opacus	Sapindaceae	4
Synsepalum longecuneatum	Sapotaceae	2

LITERATURE CITED

AMIET, J.-L. 1987. Aires disjointes et taxons vicariants chez les Anoures du Cameroun: implications paléoclimatiques. Alytes 6:99–115.

BRETELER, F. J. 1996. Tropical Africa, especially Gabon. Pp 39–49 *in* Herbarium Vadense 1896–1996, F. J. Breteler and M. S. M. Sosef, eds. Wageningen Agric. Univ. Papers 96–2.

CAMPBELL, D. G. AND H. D. HAMMOND, eds. 1989. Floristic inventory of tropical countries. New York Botanical Garden and World Wildlife Fund, United States. 545 pp.

COLYN, M., A. GAUTIER-HION AND W. VERHEYEN. 1991. A re-appraisal of palaeoenvironmental history in Central Africa: evidence for a major fluvial refuge in the Zaire Basin. J. Biogeogr. 18:403–407.

FILER, D. L. 1999. BRAHMS, Botanical Reasearch and Herbarium Management System. Referance manual for version 4.8. University of Oxford, Oxford. 738 pp.

HAMILTON, A. C. 1988. Guenon evolution and forest history. Pp. 13–34 *in* A primate radiation: evolutionary biology of the African guenons, A. Gautier-hion et al., eds. Cambridge University Press, Cambridge.

HAWTHORNE, W. D. AND M. ABU JUAM 1995. Forest protection in Ghana (with particular reference to vegetation and plant species). IUCN, Gland, Switzerland and Cambridge, United Kingdom. xvii + 203 pp.

IUCN, 1994. IUCN Red List Categories. IUCN, Gland, Switserland. 21 pp.

REITSMA, J. M. 1988. Végétation forestière du Gabon [Forest vegetation of Gabon]. Tropenbos Technical Series 1. The Tropenbos Foundation, the Netherlands. 142 pp.

SOSEF, M. S. M. 1994. Refuge begonias. Taxonomy, phylogeny and historical biogeography of *Begonia* sect. *Loasibegonia* and sect. *Scutobegonia* in relation to glacial rain forest refuges in Afica. Wageningen Agric. Univ. Papers 94–1:1–306.

WHITE, F. 1979. The Guineo-Congolian Region and its relationships to other phytochoria. Bull. Jard. Bot. Nat. Belg. 49:11–55.

A Report on the Shrews (Mammalia: Soricidae) of Monts Doudou, Gabon: Elevational Distribution and Preliminary Insights into Their Ecology

Steven M. Goodman
Field Museum of Natural History,
Roosevelt Road at Lake Shore Drive,
Chicago, Illinois 60605
email: goodman@fmnh.org

and

Rainer Hutterer
Zoologisches Forschungsinstitut und Museum Koenig,
Adenauerallee 160, D-53113 Bonn, Germany
email: r.hutterer.zfmk@uni-bonn.de

This report presents the results of a study of the shrew (Family Soricidae) community along the slopes of Monts Doudou in southwestern Gabon. No published information was previously available on these animals from this area of the country. The principal technique used to capture animals consisted of pitfall traps with drift fences. Three elevational zones were surveyed: 110 m, 375 m, and 625 m. Species richness varied from nine species at 110 m to six species at 375 and 625 m. All of these taxa were previously known from the country and have relatively broad distributions across much of the western Congo Basin. Aspects of the ecology, taxonomy, and biogeography of the Monts Doudou shrew community are discussed.

RÉSUMÉ

Ce rapport présente les résultats d'une étude effectuée sur la communauté de musaraignes (Famille Soricidae) le long du versant de Monts. Doudou dans la région sud-ouest de Gabon. Aucune information n'a encore été publiée ou disponible sur ces animaux pour cette région. La technique principale utilisée pour capturer ces animaux était le trou piège avec des barrières en plastique. Troi zone altitudinales, 110 m, 375 m et 625 m, ont été inventoriées. La richesse des espèces varie entre neuf espèces à 110 m à six espèces à 375 et 625 m. Tous ces taxa étaient connus pour le pays et ont une distribution assez large à travers un grande partie de la région ouest du Congo Basin. Des aspects relatifs à l'écologie, à la taxonomie et à la biogéographie de la communauté de musaraignes du Monts Doudou sont discutés ici.

INTRODUCTION

Little published information is available on the shrews (Family Soricidae) of Gabon. Several decades ago extensive small mammal trapping was conducted in the Ivindo River

Basin, in the northeastern portion of Gabon, associated with the Institut de Recherches en Ecologie Tropicale station at M'Passa (Makokou) (Brosset 1988). This work included some research on the local shrew communities and taxonomic studies of collected material. On the basis of these specimens several species were named new to science, which included *Suncus remyi*, *Crocidura grassei*, and *C. crenata* (Brosset et al. 1965a, 1965b). Further, a recent survey was conducted in the Minkébé region in the extreme northeastern portion of the country in an area of forest that is in a different watershed than the Makokou station (Goodman et al. 2001). To our knowledge no published survey of shrews was conducted in the rain forest zone of southern Gabon, although preliminary information is available on the soricids occurring in forested regions of neighboring countries such as the Dja Faunal Reserve in southern Cameroon (Colyn et al. 1996) and the Dzanga-Sangha Faunal Reserve of the Central African Republic (Ray and Hutterer 1996). Inventories at these sites provide the necessary information to help put the Gabon information into a regional biogeographic context.

In this paper we report the findings of a survey conducted along an elevational gradient at three sites, between 110 and 625 m, in the Monts Doudou complex. Information is presented on the species composition of the shrew community along this transect, taxonomic relations of members of this community, and initial insights into aspects of the natural history of these animals.

<center>METHODS</center>

The principal technique used to capture soricid shrews consisted of pitfall traps with drift fences. In each of the three elevational zones (110 m, 375 m, and 625 m) separate lines of these devices were placed in different microhabitats (valley bottom, along slopes of hills, and on crests of hills) in order to assess possible variation in habitat utilization by soricids. The only exception was at the 110-meter site where there was virtually no topographic relief. At this site one line was placed along a river margin and the other two in the interior of the forest.

Details on the habitats surrounding the study sites are presented in Thibault et al., this volume. The only point important to reiterate here is that the forest in the 110-meter zone had been selectively logged. Signs of this disturbance, such as stumps, in the zone surrounding pitfall traps were limited. Our access into portions of the forest was often along former logging roads used to extract timber. These partially closed routes could provide dispersal corridors for forest-edge species to enter into the forest. All of our pitfall lines were within 200 m of such trails. A logging road was located about 600 m from the 375 m camp, but no sign of selective logging was found within that surveyed zone.

Each pitfall line was 100 m long and consisted of 11 buckets (275 mm deep, 285 mm top internal diameter, 220 mm bottom internal diameter), 10 m apart, in operation for up to eight days. Buckets were sunk to a depth where the rim was even with ground level. Small holes (3–5 mm) were melted in the bottom of the buckets to allow water drainage—after heavy rain water was removed with a sponge. A barrier (drift fence) made from dark opaque plastic sheeting (0.5 m high and 100 m long) was stapled in a vertical position to thin wooden stakes. The drift fence bisected all of the buckets in each line. A flange of about 50 mm at the bottom of the standing plastic fence and resting on the ground was covered with soil and leaf litter to block animals from moving under the barrier. A bucket-night is defined as one bucket in use for a 24-hour period (dawn to dawn).

<center>94</center>

Lines of live traps (Nationals and Shermans) were also set within each of the elevational zones largely for capturing rodents. Few soricids were captured with this technique. These lines were opened for 7–8 nights. Traps were baited daily, generally between 1500 and 1700 hours, with pieces of oil palm nuts. Traps and pitfalls were visited at least twice per day, once at dawn and again in the late afternoon, and captured mammals, invertebrates, and debris were removed.

Captured animals were prepared as standard museum skins with associated skulls and skeletons, as fluid preserved carcasses, or as full skeletons. Standard external measurements and mass were taken of specimens before being prepared. Animals were divided into age classes on the basis of tooth wear patterns and the degree of fusion of the suture between the basiphenoid and basioccipital bone: young—teeth unworn, suture open; young adults—teeth slightly worn, suture closed but still visible; and adults—teeth moderately to heavily worn, suture completely fused. Voucher specimens are deposited in the Field Museum of Natural History (FMNH), Chicago, and a representative series will be returned to Gabon. The field work was conducted by SMG and the determinations of the collected material were made by RH; for the text both authors take responsibility.

<center>RESULTS</center>

General overview

In total 79 individual shrews were captured by the pitfall traps (Table 1, note the 110-meter site showed little topographic variation). In addition, 13 rodents, representing at least seven species, were also captured in these devices. The live traps resulted in the capture of four individuals and four species of shrews, all of which were documented also with the pitfall technique. About 25% of the live traps were placed off the ground, but all of the shrews captured by this technique were in ground sets. Nine species of soricids were found on the slopes of Monts Doudou—nine in the 110-meter zone and six in the 375- and 625-meter zones (Table 2). Standard external measurements and mass of these animals are presented in Table 3.

Capture rates of soricids with pitfall traps were highly variable between the sites—44 individuals were trapped at 110 m, 12 at 375 m, and 23 at 625 m and overall capture rates in each elevational zone were 16.7%, 5.2%, and 11.7%, respectively (Table 1). The number of shrews obtained within each elevational zone showed variation between the three different lines—in the 110-meter zone from 14.8–18.2%, in the 375-meter zone between 1.3–7.8%, and in the 625-meter zone between 5.2–14.3%.

These capture rates are largely comparable to those obtained during a shrew survey in the Minkébé region of northeastern Gabon, which used identical pitfall techniques at a site at about 600 m. The three pitfall lines, which each were in place at Minkébé for 110 bucket-days, yielded capture rates that ranged from 5.5–10.0% and an overall average rate of 8.5%.

Species accumulation curves

An examination of the rate of documenting previously unrecorded shrew species within each elevational zone as a function of pitfall trapping effort shows that for the 110-meter zone an apparent plateau was reached within four nights after these devices were in place (Fig. 1a). No other species was added to the local list with an additional four nights of trapping. However, for the two upper zones, at 375 and 625 m, two previously unre-

<center>95</center>

TABLE 1. Results of captures using pitfall traps in 3 elevational zones on Monts Doudou during the February–March 2000 biological inventory.

	110 m			375 m			625 m		
Line number	1	2	3	4	5	6	7	8	9
Line placements	Valley			Valley	Slope	Ridge	Ridge	Slope	Valley
First sample day	24/2	24/2	24/2	5/3	5/3	5/3	14/3	14/3	14/3
Last sample day	2/3	2/3	2/3	11/3	11/3	11/3	20/3	20/3	20/3
Total pitfall nights	88	88	88	77	77	77	77	77	77
SPECIES SAMPLED									
Mammalia, Insectivora									
Crocidura batesi	-	1	-	1	-	-	1	1	-
Crocidura crenata	-	5	1	2	-	1	2	-	-
Crocidura dolichura	1	1	-	1	-	-	1	1	2
Crocidura grassei	3	-	2	-	-	-	4	-	-
Crocidura goliath	3	1	4	-	-	1	-	-	-
Paracrocidura schoutedeni	-	1	-	-	-	-	-	-	-
Suncus remyi	-	1	-	-	-	-	-	-	-
Sylvisorex johnstoni	2	5	8	1	-	2	2	6	2
Sylvisorex ollula	4	1	-	1	1	1	1	-	-
Total shrews	13	16	15	6	1	5	11	8	4
Rodentia									
Deomys ferrugineus	-	-	1	-	-	-	-	-	-
Hybomys univittatus	-	-	-	1	-	-	-	-	-
Hylomyscus sp.	2	-	-	-	1	-	-	-	-
Lophuromys sikapusi	-	1	-	-	-	-	-	-	-
Malacomys longipes	-	-	-	-	-	-	-	-	1
Praomys spp.	-	1	3	-	-	-	-	-	1
Stochomys sp.	-	1	-	-	-	-	-	-	-
Total rodents	2	3	4	1	1	0	0	0	2
# small mammals captured	15	19	19	7	2	5	11	8	6
Capture rate small mammals	17.0%	21.6%	21.6 %	9.1%	2.6%	6.5%	14.3%	10.4%	7.8%
# soricid species captured	5	8	4	5	1	4	6	3	2
Capture rate of soricids	14.8%	18.2%	17.0%	7.8%	1.3%	6.5%	14.3%	10.4%	5.2%
Overall capture rates of soricids		16.7 %			5.2 %			10.0 %	

TABLE 2. Elevational distribution of shrews on the slopes of Monts Doudou based on all trapping techniques.

	110 m	375 m	625 m
Crocidura batesi	+	+	+
Crocidura crenata	+	+	+
Crocidura dolichura	+	–	–
Crocidura grassei	+	+	+
Crocidura goliath	+	–	+
Paracrocidura schoutedeni	+	+	–
Suncus remyi	+	–	–
Sylvisorex johnstoni	+	+	+
Sylvisorex ollula	+	+	+
Total number of species	9	6	6

corded species were found at each site during the last two nights the pitfall devices were in place.

Associated with these differences in species accumulation is notable variation in the number of individuals captured within each elevational zone (Fig. 1b). Consistently more individuals were obtained in the pitfall traps at 110 m than the other two zones. The addition of previously unrecorded species late in the trapping session in the upper two sites is almost certainly related to low capture rates. As a result we are uncertain if our measure of the number of shrews occurring in the upper two sites truly reflects the species richness of the locally occurring community.

Age variation

Age of collected individuals was determined on the basis of cranial and dental development and wear. Between the nine species of shrews captured on the slopes of Monts Doudou there was considerable variation in age structure (Table 4). We interpret these results to indicate that differences exist amongst these species in the breeding season. Shrews of genus *Crocidura* develop after a mean gestation period of 30 days (Vogel 1972, Innes 1994), into age class "young" about 20 days after birth, and into age class "young-adult" about a month later (Vlasák 1970). Of the eight individuals of *Sylvisorex ollula* trapped, four were young and four were young adults, while for *S. johnstoni* no young were obtained but four young-adults and 20 adults. Thus, we assume that these species have relatively discrete breeding seasons. The results suggest that *S. ollula* had recently completed a reproductive period as young individuals dominated the population. The breeding period of *S. johnstoni* was most likely a few months before our inventory. Although the number of individuals of *Crocidura batesi* and *Paracrocidura* captured were somewhat limited, they showed parallels in age structure to *S. johnstoni*. In other cases, such as *C. goliath* and *C. crenata*, about half of the trapped individuals were adults, but the other two age classes were also represented. This might indicate that the breeding period for these two species is not as temporally well defined as in the two *Sylvisorex* and there is less skewing of the age structure. Although these data indicate that there maybe discrete breeding periods for several species of shrews on the slopes of Monts Doudou, the information is insufficient to draw definitive conclusions about seasonality and the environmental cues of reproduction in these animals.

97

TABLE 3. External measurements of different shrew species captured during the Monts Doudou survey.

	Total length	Head and body	Tail length	Hind foot	Ear	Mass
Crocidura batesi - young adult	145	82	59	15	11	10.5
adult	143 ± 5.05 137-158, n=4	78 ± 3.67 72-88, n=4	57.5 ± 1.89 52-60, n=4	14.3 ± 0.25 14-15, n=4	11.5 ± 0.29 11-12, n=4	12.7 ± 1.32 9.1-15.5, n-4
Crocidura crenata - young	159	65	86	16, 16	10, 11	6.2
young adult	160 ± 2.74 153-166, n=4	66.3 ± 1.25 63-69, n=4	86.5 ± 2.90 15-16, n=4	15.5 ± 0.29 15-16, n=4	11.3 ± 0.25 11-12, n=4	6.8 ± 0.57 5.6-7.8, n=4
adult	164 ± 4.71 138-177, n=7	72.4 ± 1.99 62-79, n=7	85.1 ± 2.59 72-91, n=7	15.7 ± 0.18 15-16, n=7	10.1 ± 0.55 7-11, n=7	8.4 ± 0.26 7.8-9.1, n=5
Crocidura dolichura - young	165, 158	66, 62	93, 89	13, 13	9, 9	5.1, 4.4
Crocidura grassei - young	160, 156	72, 75	83, 77	18, 15	11, 11	11.0, 9.5
young adult	157, 162	76, 82	75, 73	16, 16	10, 11	10.0, 12.5
adult	167.8 ± 4.67 157-177, n=4	81.3 ± 2.29 76-86, n=4	76.8 ± 2.60 69-80, n=4	15.8 ± 0.48 15-16, n=4	10.8 ± 0.48 10-12, n=4	11.6 ± 0.47 11-13, n=4
Crocidura goliath - young	205.7 ± 6.84 192-213, n=3	113.0 ± 4.93 105-122, n=3	83.3 ± 3.84 79-91, n=3	21.3 ± 0.67 20-22, n=3	13.7 ± 0.33 13-14, n=3	29.5 ± 2.78 26-35, n=3
young adult	227 ± 3.06 223-233, n=3	126.3 ± 2.91 121-131, n=3	87.0 ± 2.00 85-91, n=3	21.0 ± 1.00 20-23, n=3	15.0 ± 0.58 14-16, n=3	48.3 ± 2.90 43-53, n=3
adult	239.4 ± 6.95 220-252, n=5	136.8 ± 5.45 122-150, n=5	92.0 ± 1.22 89-96, n=5	21.6 ± 0.87 19-23, n=5	14.8 ± 0.58 13-16, n=5	48.1 ± 4.15 38-57, n=5
Paracrocidura schoutedeni - young adult	226.7 ± 2.40 112-120, n=3	69.0 ± 2.65 65-94, n=3	38.0 ± 4.16 30-44, n=3	12.0 ± 0.58 11-13, n=3	8.7 ± 0.33 8-9, n=3	8.3 ± 0.55 7.3-9.3, n=3
adult	116.7 ± 4.10 109-123, n=3	72.3 ± 3.7 65-76, n=3	38.7 ± 2.40 34-42, n=3	10.3 ± 0.33 10-11, n=3	9.0 ± 0.58 8-10, n=3	11.0 ± 1.26 8.5-12.5, n=3
Suncus remyi - adult	74	49	19	6	6	1.7
Sylvisorex johnstoni - young adult	84.3 ± 3.32 79-94, n=4	46.3 ± 0.95 45-49, n=4	31.5 ± 1.32 29-35, n=4	9.0 ± 0.0 9-9, n=4	8.0 ± 0.0 8-8, n=4	2.5 ± 0.08 2.4-2.7, n=4
adult	85.5 ± 0.99 76-91, n=17	48.5 ± 0.69 45-53, n=17	32.1 ± 0.73 25-36, n=17	9.2 ± 0.20 8-12, n=17	8.2 ± 0.15 7-9, n=14	2.9 ± 0.10 2.3-3.5, n=11
Sylvisorex ollula - young	152.8 ± 4.44 142-161, n=4	80.3 ± 0.85 78-82, n=4	65.5 ± 2.84 59-72, n=4	15.5 ± 0.65 14-17, n=4	12.3 ± 0.25 12-13, n=4	11.9 ± 0.63 10.5-13.5, n=4
young adult	155.8 ± 2.75 151-163, n=4	83.0 ± 0.58 82-84, n=4	63.8 ± 2.06 60-69, n=4	14.5 ± 0.29 14-15, n=4	11.5 ± 0.29 11-12, n=4	13.7 ± 0.44 13.0-14.5, n=3
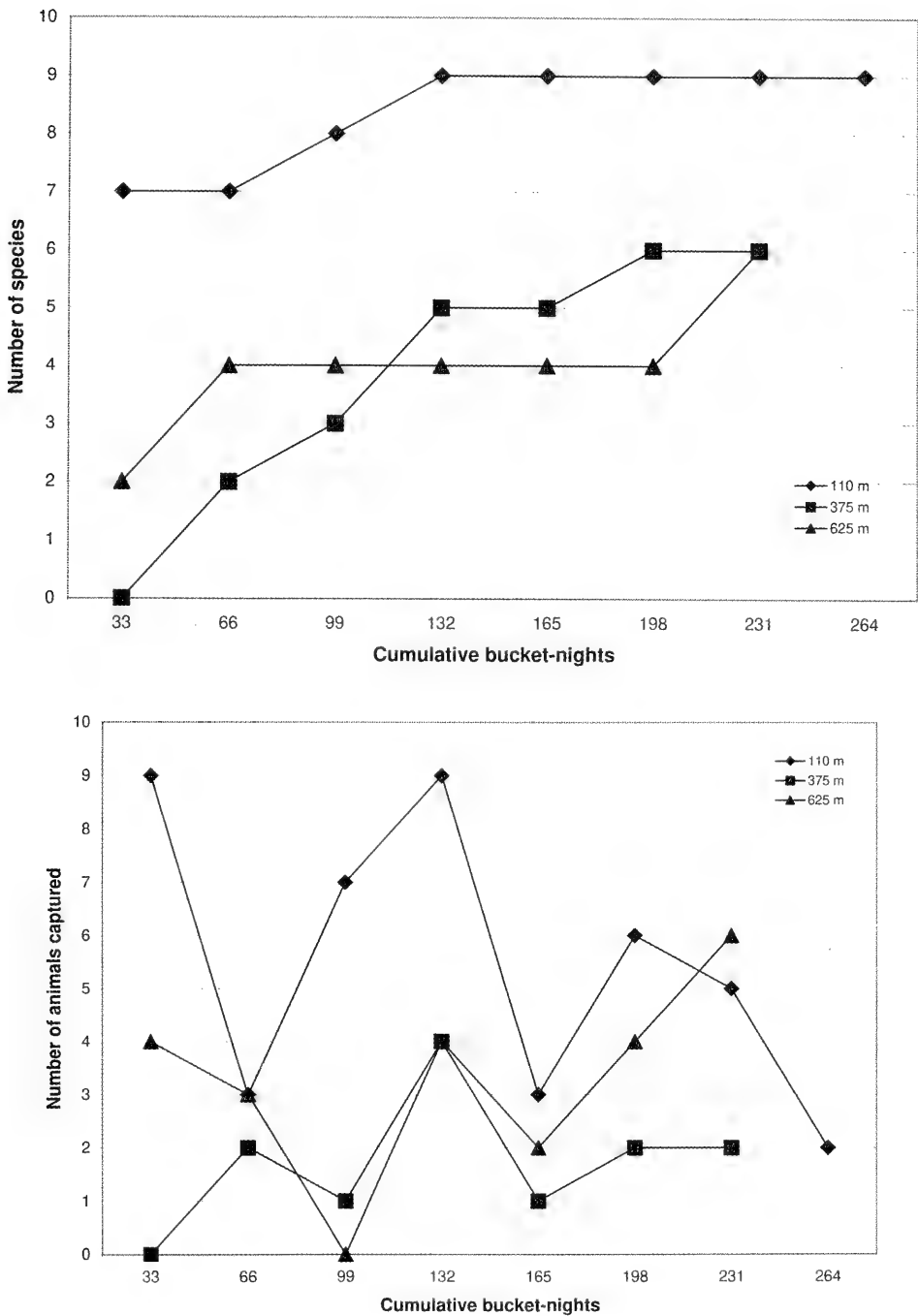
FIGURE 1. Species accumulation curves (A) and pitfall trap success (B) plotted for each elevational zone on Monts Doudou against the total number of bucket-nights. The pitfall lines were placed in three different elevational zones (110, 375, and 625 m). Information from the three lines in each zone is combined here.

Sex ratios

For a few species the number of male and female specimens collected did not deviate from being equal (Table 4). Species that fall into this group include, for example, *Crocidura batesi*, *C. goliath*, *Sylvisorex johnstoni,* and *S. ollula*. Several other species showed skewed sex ratios. Not a single female was represented of the eight *C. grassei* and six *Paracrocidura* captured. Clearly these figures do not represent primary sex ratios in nature, but rather some life-history traits of these animals that are reflected by our trapping techniques. One possible factor is that, for these two species, males are more active or perhaps have larger home ranges or patrol territory boundaries and, thus, have a greater chance of being captured.

Microhabitat differences

On the basis of current data, there are no clear differences between the three zones surveyed on Monts Doudou in measures of either relative density or species richness between the different microhabitat types the pitfall lines were placed. For example, in the 110-meter zone approximately equal numbers of shrews were taken in the three pitfall lines. This is compared to the 375-meter zone where 50% of the animals were obtained in the valley line, 42% on a ridge, and 8% on a slope—the comparable figures for the 625-meter zone for these three types of pitfall placements were 17%, 48%, and 35%, respectively. Thus, there appears to be no consistent pattern between capture rates and microhabitat.

The greatest number of species obtained in any single pitfall line on the mountain was one placed on upper flat ground in the 110-meter zone, where eight species were trapped. This represents eight of nine (89%) shrew species obtained in the zone or along the complete Monts Doudou elevational transect. The valley line in the 375-meter zone captured five of six (83%) of the species known from this elevation and the ridge line in the 625-meter zone six of six (100%) identified from this zone. The other pitfall traps placed in these two zones had lower capture rates and, with the exception of one species at 375 m, all were a subset of these taken in the line with the highest species richness.

SPECIES ACCOUNTS AND TAXONOMIC COMMENTS

Crocidura batesi Dollman, 1915

Two of the individuals of this species collected during the 2000 inventory of Monts Doudou were obtained by means other than pitfall traps. Brian Fisher found one adult during the day in a hollow portion of a log resting on the ground. It was in a cavity measuring

TABLE 4. Aspects of age structure and sex ratio of captured soricids on the slopes of Monts Doudou.

	Age ratio young:young adult:adult	Sex ratio male:female
Crocidura batesi	0:1:4	1:4
Crocidura crenata	2:4:7	9:4
Crocidura dolichura	2:0:0	0:2
Crocidura grassei	3:3:5	7:4
Crocidura goliath	2:2:4	8:0
Paracrocidura schoutedeni	0:3:3	6:0
Suncus remyi	0:0:1	1:0
Sylvisorex johnstoni	0:4:20	12:14
Sylvisorex ollula	4:4:0	5:3

about 10×6 cm. The second individual was trapped in a cleared forest zone with short herbaceous vegetation and about 5 m from the forest edge. The trap was placed next to a rotten log.

This species was obtained across the complete elevational transect of Monts Doudou. It may have a slight preference for lower and wetter ground. All three animals trapped in the 110-meter zone, the single individual in the 375-meter zone, and two of the four in the 625-meter zone were captured in pitfall traps placed in valleys along river margins.

The species limits of *C. batesi* are unknown (Goodman et al. 2001). Morphologically the specimens from Monts Doudou agree well with specimens from coastal Cap Esterias, Gabon (vouchers in the Carnegie Museum, Pittsburgh, and Museum Koenig, Bonn), and both Gabonese samples appear to be smaller than populations in southern Cameroon, for which a standard karyotype is known (Schlitter et al. 1999).

Crocidura crenata Brosset, Dubost, and Heim de Balsac, 1965

Brosset (1988) noted that the long feet and tail of this species are probably adaptations for jumping, rather than being at least partially arboreal. We did not capture this species in traps placed off the ground.

The series of 13 specimens from Monts Doudou (Table 3) increases our knowledge on the size variation of this little-known species. External measurements show that the tail length is about equal in *C. crenata* and *C. dolichura*, and thus cannot be used to differentiate this species. The hindfoot length (15 versus 13 mm) is the only useful external character that separates the two species.

Crocidura crenata has been regarded previously as rare (Nicoll and Rathbun 1990). This view is no longer true; in the Monts Doudou community it is the second-most common species (Table 1).

Crocidura dolichura Peters, 1876

This species was only collected in the 110-meter zone at the foot of Monts Doudou. Both specimens were taken in pitfall traps placed in forest, one in a valley bottom within the flood plain of a small river and the other in slightly higher and flatter ground.

The two young specimens caused some identification problems; their skulls resembled *C. latona* Hollister, 1916 or *C. maurisca* Thomas, 1904 (the latter was recently recorded from Gabon by Goodman et al. 2001), but a careful comparison with the holotype of *C. dolichura* in the Berlin Museum (also figured in Brosset et al. 1965a) revealed that they represent the typical form of *C. dolichura* (type locality: Bonjongo, Cameroon). Other populations from the central and eastern Congo Basin are slightly different: the tails are often longer and the skulls are larger, with a higher braincase and smaller upper incisors. The geographic variation of *C. dolichura*, as currently understood, obviously requires a careful analysis.

Crocidura goliath Thomas, 1906

The only individual of this species obtained by means other than pitfall traps was in the 110-meter zone and in a Sherman trap placed on the ground under the fallen tree branches.

The skulls and bodies of the Monts Doudou series are rather small as compared to *C. goliath* from the type locality (Efulen, S. Cameroon), but also from the Minkébé Forest in northern Gabon (Goodman et al. 2001) and from Equatorial Guinea (Lasso et al. 1996). This raises the question whether the Monts Doudou population is referable to *Sorex odoratus* Leconte, 1857 (type locality: Cette Cama, Gabon), a name currently taken as a

synonym of *C. olivieri* (Hutterer 1995). If the type material of *C. odorata* is referable to the *C. goliath* morphotype, then *C. odorata* would have priority. Until this taxonomic problem has been solved we retain the well-known and well-defined name *C. goliath* for the giant forest shrew.

Crocidura grassei Brosset, Dubost, and Heim de Balsac, 1965
    Previously this large and colorful species (grey fur, pale extremities, long tail) was considered as rare (Nicoll and Rathbun 1990; Goodman et al. 2001). The Monts Doudou survey suggests that the species may be locally common.

Paracrocidura schoutedeni Heim de Balsac, 1956
    A typical member of the lowland forest of the Congo Basin.

Suncus remyi Brosset, Dubost, and Heim de Balsac, 1965
    In the 110-meter zone a single individual was obtained in a Sherman trap placed on the ground next to the base of a large tree with buttressed roots. This tiny shrew is an uncommon but widespread member of shrew communities in the western Congo Basin.

Sylvisorex johnstoni (Dobson, 1888)
    This is the dominant species of the Monts Doudou community (Table 1).

Sylvisorex ollula Thomas, 1913
    Like *S. johnstoni, C. crenata, C. grassei*, and *Suncus remyi*, this is a typical member of the lowland forest communitites in the western Congo Basin.

DISCUSSION

The use of pitfall traps
    One important question associated with rapid inventories of forested areas with a highly diverse small mammal fauna is how effective the sampling techniques and associated estimates of local species richness are with respect to that actually occurring in the surveyed zone. Within close proximity to our 110-meter site another study on small mammals was conducted that used a similar pitfall trap protocol as our work and that was in place over several months (Nicolas et al., this volume). A comparison of the results of these two studies indicates that the species captured during the rapid inventory (eight nights of trapping) are identical to those captured during the long term study. These data indicate that when pitfall lines are placed in different habitats within a site the technique is rather effective in rapidly providing a good measure of the local species of Soricidae.

Age structure and reproduction
    Our data indicate that some shrew species obtained on Monts Doudou did not reproduce during the study period (February and March), while others did. Comparative data on reproductive strategies and annual reproductive cycles of tropical African shrews are scanty. Dieterlen and Heim de Balsac (1979) presented the most comprehensive data set yet obtained during an ecological study of shrews in the eastern Congo. Their results show that the reproduction cycle of shrews in that area is bimodal and roughly follows the rainfall pattern. On the other hand, Atanda wa Sandako (1984), based on a study of *Crocidura*

olivieri in the environs of Kisangani (Democratic Republic of Congo), concluded that the species reproduces all year long.

Species richness and elevational variation

Nine species of shrew were recorded in the survey of the eastern slopes of Monts Doudou between 110 and 625 m. The highest species richness was in the lowest elevational zone at 110 m, where all nine forms found on the mountain were collected, and the sites at 375 m and 625 m each had six species. This pattern of highest species richness in the lowland forest differs markedly from other small mammal surveys in African montane zones where there is generally an increase in species richness and endemism with increasing elevation (Heim de Balsac 1968; Hutterer et al. 1987).

The Monts Doudou survey commenced at a relatively low elevation and terminated just below the summit of the massif (about 650 m). This elevational gradient is considerably different from the majority of small mammal surveys conducted in the tropical portion of Africa with regards to the altitudinal swath studied. Previously conducted shrew transects elsewhere on the continent generally commence and terminate in higher zones. For example, in the Ruwenzori Mountains a shrew survey spanned the elevational range from 1960 to 4000 m (Kerbis Peterhans et al. 1998). In all cases the elevational swath of these altitudinal transects were much broader than our survey on Monts Doudou, and thus, it is difficult to compare questions of differences in species richness as a function of elevation between these sites.

The 110-meter zone was the only surveyed area that showed clear signs of human habitat disturbance, which was confined to selective logging. Although these activities seemed to have little effect on the habitat quality of this zone, telltale signs of tree extraction were limited. It is possible that roads, put in place to extract logs, provide dispersal corridors for forest-edge species of shrew. However, no clear evidence was found for shrews of such taxa.

Biogeography and Pleistocene refugia

The shrew fauna found on Monts Doudou is to a large extent represented by species with broad distributions at other surveyed sites in the western portion of the Congo Basin. For example, a comparison of the species collected during an inventory in the northeastern corner of Gabon, in the Minkébé forest (Goodman et al. 2001), that used identical techniques to the Monts Doudou survey, shows that the shrew faunas of these two sites are largely identical.

Three species of shrews, *Crocidura grassei*, *C. crenata,* and *Suncus remyi*, were described thirty-five years ago from the Makokou region of northeastern Gabon (Brosset et al. 1965a, 1965b). Until recent survey work in other sites in the Congo Basin (Hutterer and Schlitter 1996; Ray and Hutterer 1996) these shrews were poorly known. Subsequently, all three species were found in both the Minkébé and Monts Doudou forests, and it would appear that their previously presumed limited distribution was simply a matter of a lack of survey work. The other species known from the Makokou region are part of the same set documented in these other regional forest blocks. The shrew fauna across this zone of the western Congo Basin appear to show a high level of homogeneity.

On the basis of botanical evidence it has been postulated that the summital zone of Monts Doudou retains remnants of distinct floristic elements that have phytogeographic affinities to montane zones in areas surrounding the Congo Basin and greater western-central Africa. One of the more notable groups along these lines is the genus *Begonia* (Sosef 1994,

1996). The presence of these elements has been interpreted as representing vestiges of a floral community dating from an earlier geological period, presumably the Pleistocene, when changes in climate resulted in altitudinal shifts in vegetation structure. The presence of these plants towards the summit of Monts Doudou has been interpreted that this zone holds floral vestiges of montane flora that currently rings the Congo Basin and this portion of the massif is a Pleistocene refuge.

Little information was available on the small mammals occurring in montane zones of Gabon, and it was unclear if parallel vestiges within this community could be found in the Monts Doudou complex. Examples of such remnants might include *Crocidura eisentrauti* Heim de Balsac, 1957, known from the upper slopes of Mt. Cameroon, *C. manengubae* Hutterer, 1981, known from highlands in western Cameroon, or *C. stenocephala* Heim de Balsac, 1979, *C. lanosa* Heim de Balsac, 1968, and *C. kivuana* Heim de Balsac, 1968, restricted to the mountains of the Kahuzi-Biega region of eastern Congo. Within the Monts Doudou shrew fauna we found no evidence of species previously thought to be restricted to montane zones ringing the Congo Basin. Although there were some shifts in the vegetational types between the lowland and upper sites that were surveyed on Monts Doudou, the 625-meter zone by no means held a distinct montane or mossy forest plant community. Given that the summital zone of the massif that was surveyed reached about 650 m, and the highest peak in the Monts Doudou range is 800 m, it is not altogether surprising that no species of shrew was found representing a biogeographic link to montane species occurring in the region surrounding the basin. If such a fauna exists in Gabon, the summital zones of Monts Cristal, which reaches 1022 m, might harbor such elements.

LITERATURE CITED

ATANDA WA SANDAKO, BOSONGO. 1984. Contribution a l'étude de la biologie de *Crocidura occidentalis* (Pucheran 1855) (Mammifère Insectivore) dans le milieu rural de Kisangani. Memoire, Université de Kisangani. 40 pp.

BROSSET, A. 1988. Le peuplement de mammifères insectivores des forêts du Nord-Est du Gabon. Revue Ecol. 43:23–46.

BROSSET, A., G. DUBOST, AND H. HEIM DE BALSAC. 1965a. Une nouvelle espèce de *Crocidura* du Gabon. Mammalia 29:268–274.

———. 1965b. Mammifères inédits récoltés au Gabon. Biologia Gabonica 1:147–174.

COLYN, M., D. CORNELIS, AND O. PERPETE. 1996. Synthèse "Micro-mammifères" Muridae et Soricidae Structure des peuplements: richesse et diversité spécifiques et Indices d'abondance. Report to Projet ECOFAC.

DIETERLEN, F. AND H. HEIM DE BALSAC. 1979. Zur Ökologie und Taxonomie der Spitzmäuse (Soricidae) des Kivu-Gebietes. Säugetierkundliche Mitteilungen 27:241–287.

GOODMAN, S. M., R. HUTTERER, AND P. R. NGNEGUEU. 2001. A report on the community of shrews (Mammalia: Soricidae) occurring in the Minkébé Forest, northeastern Gabon. Mammalian Biology (Z. Säugetierkunde) 66:22–34.

HEIM DE BALSAC, H. 1968. Considerations preliminaires sur le peuplement des montagnes africaines par les Soricidae. Biologia Gabonica 4:299–323.

HUTTERER, R. 1995. Order Insectivora. Pp. 69–130 *in* Mammal Species of the World: a Taxonomic and Geographic Reference. Second, corrected edition, D. E. Wilson and D. A. Reeder, eds. Smithsonian Institution Press, Washington, D.C.

HUTTERER, R. AND D. A. SCHLITTER. 1996. Shrews of Korup National Park, Cameroon, with the description of a new *Sylvisorex* (Mammalia: Soricidae). Pp. 57–66 *in* Contributions in Mammalogy: A Memorial Volume Honoring Dr. J. Knox Jones, Jr. Museum of Texas Tech University, Lubbock.

HUTTERER, R., E. VAN DER STRAETEN, AND W. VERHEYEN. 1987. A checklist of the shrews of Rwanda and biogeographical considerations on African Soricidae. Bonner zoologische Beiträge 38:155–172.

INNES, D. G. L. 1994. Life histories of the Soricidae: a review. Carnegie Museum of Natural History, Special Publication 18:111–136.

KERBIS PETERHANS, J. C., R. M. KITYO, W. T. STANLEY, AND P. K. AUSTIN. 1998. Small mammals along an elevational gradient in Rwenzori Mountains National Park, Uganda. Pp. 149–171 *in* The Ruwenzori Mountains National Park, Uganda, H. Osmaston, J. Tukahirwa, C. Basalirwa, and J. Nyakaana, eds. Department of Geography, Makerere University, Kampala.

LASSO, C., R. HUTTERER, AND A. RIAL. 1996. Records of shrews (Soricidae) from Equatorial Guinea, especially from Monte Alen National Park. Mammalia 60:69–76.

NICOLL, M. E. AND G. B. RATHBUN. 1990. African Insectivora and Elephant-Shrews, an action plan for their conservation. IUCN, Gland. 53 pp.

RAY, J. C. AND R. HUTTERER. 1996. Structure of a shrew community in the Central African Republic based on the analysis of carnivore scats, with the description of a new *Sylvisorex* (Mammalia: Soricidae). Ecotropica 1:85–97.

SCHLITTER, D. A., R. HUTTERER, T. MADDALENA, AND L. W. ROBBINS. 1999. New karyotypes of shrews (Mammalia: Soricidae) from Cameroon and Somalia. Annals of Carnegie Museum 68:1–13.

SOSEF, M. S. M. 1994. Glacial rainforest refuges and begonias. Wageningen Agric. Univ. Papers 94–1:113–121.

SOSEF, M. S. M. 1996. Begonias and African rainforest refuges: general aspects and recent progress. Pp. 602–611 *in* The biodiversity of African plants, L. J. G. van der Maesen et al., eds. Kluwer Academic.

VLASAK, P. 1970. The biology of reproduction and post-natal development of *Crocidura suaveolens* Pallas, 1811 under laboratory conditions. Acta Universitas Carolinae, Biol. 3:207–292.

VOGEL, P. 1972. Vergleichende Untersuchung zum Ontogenesemodus einheimischer Soriciden (*Crocidura russula, Sorex araneus* und *Neomys fodiens*). Revue suisse de Zoologie 79:1201–1332.

Variabilité Structurale des Peuplements Forestiers de Rongeurs (Muridae) et Musaraignes (Soricidae) dans les Monts Doudou, Gabon

Violaine Nicolas

UMR-CNRS 6552, Université de Rennes 1, Station Biologique,
F-35380 Paimpont, France
email: Violaine.Nicolas@univ-rennes1.fr

Patrick Barrière

UMR-CNRS 6552, Université de Rennes 1, Station Biologique,
F-35380 Paimpont, France
email: Patrick.Barriere@univ-rennes1.fr

Sylvain Guimondou

Direction de la Faune et de la Chasse, B.P. 1128 Libreville, Gabon

Marc Colyn

UMR-CNRS 6552, Université de Rennes 1, Station Biologique,
F-35380 Paimpont, France
email: Marc.Colyn@univ-rennes1.fr

A long term study, to investigate structural variation of non-flying small mammal communities (Muridae and Soricidae), at different spatial and temporal scales and at two localities 2.5 km apart, was conducted in lowland forest (110 m A.S.L.). At each locality, three forest habitats were surveyed: *"terra firme* forest," "riverine forest," and "swamp forest." In total, 1198 rodents and 503 shrews were captured using two sampling protocols (Sherman and snap-traps, and pitfall traps). Nine genera and twelve species of Muridae (*Deomys ferrugineus, Heimyscus fumosus, Hybomys univittatus, Hylomyscus aeta, H. stella, H. parvus, Lophuromys nudicaudus, Malacomys longipes, Praomys* sp. 1, *Praomys* sp. 2, *Stochomys longicaudatus* and *Thamnomys rutilans*), and four genera and nine species of shrews (*Crocidura batesi, C. crenata, C. dolichura, C. goliath, C. grassei, Paracrocidura schoutedeni, Suncus remyi, Sylvisorex johnstoni* and *S. ollula*) were collected. The murid fauna of Monts Doudou is representative of west central Africa. In contrast, the soricid community richness is lower than that found at most localities surveyed in the Congo Basin. No mountain forest species and/or species endemic of the coastal Atlantic region was collected. Global trap success is higher in swamp forest for rodents, while shrews are more abundant in *terra firme* forest. In *terra firme* forest, at the locality where shrews are more numerous, rodents were fewer and vice versa. Finally, we found structural and/or population dynamic variations in the two mammal groups between the three habitat types, and also between the two localities in the *terra firme* habitat.

INTRODUCTION

Depuis le milieu des années soixante, un nombre croissant d'études sont menées en Afrique tropicale sur les rongeurs (F: Muridae) et les musaraignes (F: Soricidae). Les études écologiques de ces micro-mammifères sont difficiles en raison de leur petite taille, et de leur comportement souvent nocturne et discret (Duplantier 1982). A ces problèmes de terrain, s'ajoutent des difficultés taxinomiques et d'identification des animaux puisqu'il existe des complexes d'espèces phénotypiquement très similaires (Qumsiyeh et al. 1990; Hutterer 1993; Denys et al. 1994). Cependant, les études menées jusqu'à présent ont permis de s'affranchir en partie de ces difficultés, d'une part en définissant des méthodes de suivi adéquates (Brosset 1966; Neal et Cock 1969; Colyn et al. 1996), et d'autre part en améliorant considérablement nos connaissances systématiques et taxinomiques sur les Muridae (e.g., Brosset et al. 1965; Van der Straeten et Dieterlen 1987; Van der Straeten et Dudu 1990; Verheyen et al. 1996) et les Soricidae (e.g., Maddalena 1990; Maddalena et Ruedi 1994; Schlitter et al. 1999; Quérouil et al. 2001). A ce jour, diverses missions d'inventaires en Afrique centrale ont permis de décrire de nouvelles espèces et de dresser des listes pour de nombreux sites de République centrafricaine (Petter et Genest 1970; Ray et Hutterer 1995; Barrière et Nicolas 2000), République du Congo (Granjon 1991; Colyn et al. 1996), République Démocratique du Congo (Dudu 1991), Cameroun (Hutterer et Schlitter 1996; Colyn et al. 1996), et Guinée équatoriale (Lasso et al. 1996). Au Gabon, des études ont été menées à Bélinga-Makokou par Duplantier (1982) et Brosset (1988), à Minkébé par Goodman et al. (2001), en forêt des Abeilles par Colyn et al. (1996). En revanche, aucune donnée n'est disponible pour le Sud du Gabon, et plus particulièrement pour la région des Monts Doudou.

Barrière (1997b), Nicolas (1999) et Barrière et Nicolas (2000) ont montré l'existence, en Afrique tropicale, de variations de structure des communautés micro-mammifères à diverses échelles spatiales (entre sites appartenant à des pays ou régions distincts, mais aussi entre sites distants de quelques dizaines de kilomètres et appartenant à un même bloc forestier) et temporelles (variations inter et intra-annuelles). Nous avons voulu tester si à une échelle encore plus petite, entre sites distants de seulement quelques kilomètres, la structure des peuplements micro-mammifères variait, et si les variations temporelles observées au cours d'un cycle annuel étaient synchrones entre ces deux sites.

Les objectifs de cette étude sont donc (1) de participer à l'inventaire des Muridae et Soricidae de la forêt de basse altitude en vue de définir le statut à donner à cette région, et (2) de tester la stabilité en termes de composition et de structure des deux peuplements sur deux sites d'étude proches et dans un même type d'habitat. Nous présentons ici, à titre préliminaire, les résultats des 7 premiers mois du cycle annuel.

SITES D'ETUDE, MATERIEL ET METHODES

Sites d'étude

Notre étude a été réalisée en forêt de basse altitude (110 m A.S.L.), au niveau de la rivière Moueva, à 14 km du village de Doussala (02°09′S, 10°30′E). Deux sites (A et B), d'une surface de 1 km² chacun, et distants de plus de 2.5 km ont été choisis.

Protocole d'échantillonnage

Chaque mois, sur chacun des 2 sites d'étude, deux types de dispositifs ont été mis en place: (i) une ligne de Pitfall de 30 seaux (espacés de 5 m; soit 150 m de long) pendant 21

jours et (ii) 3 lignes de 200 pièges (Sherman et tapette métallique en alternance, espacés de 5 m, soit 1 km de long) pendant 7 jours. Ces dispositifs sont détaillés par Nicolas et Barrière (2001).

La forêt de basse altitude de la zone étudiée constitue une véritable mosaïque de forêts de terre ferme, et de forêts sur sol hydromorphe ripicole inondable ou marécageux. Etant donnée leur étendue, nos dispositifs mensuels traversent fréquemment ces 3 types de forêt. Au démarrage de l'étude (février-mars 2000), nous avons également réalisé quelques tests préliminaires dans chacun de ces types d'habitat: (1) 1 ligne Pitfall de 30 seaux pendant 21 jours en forêt de terre ferme; (2) 1 ligne Pitfall de 30 seaux pendant 14 jours en forêt ripicole et (3) 1 ligne Pitfall de 20 seaux pendant 14 jours en forêt marécageuse.

Les appâts des pièges Shermans et tapettes (manioc) ont été renouvelés tous les deux à trois jours. Les pièges ont été visités au levé du jour. La pluviométrie a été mesurée, chaque matin, pendant les 21 jours mensuels de piégeage.

Matériel biologique

Tous les spécimens ont été euthanasiés, puis pesés, mesurés (corps, queue, pied, oreille), sexés, les caractères de reproduction identifiés, une biopsie a été prélevée et conservée en alcool, les corps ont été fixés au formol 10% et les crânes conservés en alcool avant d'être préparés au laboratoire. La détermination des spécimens a été tout d'abord réalisée sur base de leurs caractéristiques morphologiques externes, puis elle a été confirmée par une analyse crânio-dentaire par comparaison avec des spécimens de référence. L'ensemble de la collection est actuellement à la Station Biologique de Paimpont (France) et un échantillon représentatif sera renvoyé au Gabon.

Analyse des données

Les variables écologiques suivantes ont été analysées:

1. l'effort de piégeage E (nuit.pièges): une nuit.piège représente un piège disposé pendant une durée de 24 heures (d'aube à aube); l'effort de piégeage est donc calculé en multipliant le nombre de nuits de piégeage par le nombre de pièges mis en place;

2. la richesse générique et spécifique (S): nombre de genres et d'espèces;

3. le sexe ratio M/F: rapport du nombre de mâles sur le nombre de femelles;

4. la proportion de femelles en phase de reproduction: rapport (%) du nombre de femelles gestantes ou allaitantes sur le nombre total de femelles;

5. le nombre moyen d'embryons par femelle gravide;

6. la densité relative: nombre d'animaux capturés pour un effort de piégeage de 100 nuit.pièges. Cette densité relative correspond donc au succès de capture. La densité relative globale (T, %) se définie comme la densité relative de toutes les espèces confondues d'un même groupe taxinomique (Muridae ou Soricidae). La densité relative spécifique (Ti, %) se définit comme la densité relative d'une espèce donnée;

7. l'abondance relative d'une espèce pi (%): pourcentage de l'effectif de la population d'espèce i (ni) sur la somme des effectifs des S espèces constituant le peuplement (N);

8. la biomasse relative globale B (g, %): biomasse de toutes les espèces confondues, d'un groupe taxinomique, pour un effort de piégeage de 100 nuit.pièges. La biomasse relative d'une espèce (bi, %): rapport de la biomasse de la population d'espèce i sur la somme des biomasses des S espèces constituant le peuplement. La biomasse est calculée en multipliant le poids moyen des individus de chaque espèce par le nombre d'individus de chaque espèce.

Le coefficient de corrélation de rang de Spearman a été utilisé comme mesure de la corrélation entre les abondances relatives des espèces entre les deux sites d'étude. Le test du Xhi carré a été utilisé pour tester l'hypothèse d'une répartition uniforme des individus entre les sites A et B, ou entre habitats distincts; et entre les deux sexes.

L'ensemble des résultats obtenus (de février à octobre avec les deux types de dispositifs, Pitfalls et Sherman-tapettes) interviennent dans l'inventaire des espèces, l'étude de la reproduction et du sex-ratio. Les rongeurs sont principalement capturés en Sherman-tapettes et les musaraignes en Pitfalls. Pour l'étude de la richesse spécifique nous avons pris en compte les résultats obtenus avec les deux types de dispositifs. A l'inverse, pour le calcul des densités et abondances relatives nous ne considérerons que les résultats des pièges Sherman-tapettes pour les muridés, et des pièges Pitfalls pour les soricidés. Pour l'étude des préférences écologiques des espèces (sol plus ou moins hydromorphe), nous avons pris en compte les résultats obtenus en février-mars pour les musaraignes, et ceux obtenus d'avril à octobre pour les muridés. Ces périodes correspondent à celles pour lesquelles les piégeages ont pu être réalisés simultanément dans les 3 types de forêt.

RESULTATS

MURIDAE

Au total, 1136 Muridae ont été capturés en Sherman-tapettes (T = 1.94%), et 62 en Pitfalls (T = 0.62%). Neuf genres et 12 espèces ont ainsi été recensés: *Deomys ferrugineus* (N = 31), *Heimyscus fumosus* (N = 122), *Hybomys univittatus* (N = 203), *Hylomyscus aeta* complexe (N = 6), *H. parvus* (N = 3), *H. stella* (N = 466), *Lophuromys nudicaudus* (N = 11), *Malacomys longipes* (N = 62), *Praomys* sp. 1 (N = 54), *Praomys* sp. 2 (N = 197), *Stochomys longicaudatus* (N = 1) et *Thamnomys rutilans* (N = 2). Dix espèces ont été capturées en Sherman-tapettes, et 12 l'ont été en Pitfalls. La combinaison de ces deux types de pièges est intéressante puisque certaines espèces rares de rongeurs (*Hylomyscus aeta, H. parvus, S. longicaudatus* et *T. rutilans*) ont été relativement bien, voire exclusivement, capturées en Pitfall.

Après analyse crânio-dentaire deux espèces de *Praomys* sont présentes dans la localité étudiée: *Praomys* sp. 1 et *Praomys* sp. 2. Une révision taxinomique de ce genre est en cours, et nous ne pouvons pas, à l'heure actuelle, leur donner un nom. Ces deux espèces appartiennent au complexe *P. tullbergi* et se distinguent non seulement d'un point de vue craniologique mais aussi génétique (séquençage ADNr 16S); elles correspondent aux espèces nommées respectivement "C" et "D" par Nicolas (1999). Après observation crânienne, 13% des *Praomys* restent indéterminés; ces spécimens correspondent soit à de jeunes individus, soit à des individus dont le crâne a été fracturé (animaux capturés en tapettes).

Reproduction

La reproduction des trois espèces les plus abondantes (*Hybomys univittatus, Hylomyscus stella* et *Praomys* sp. 2) semble effective d'avril à octobre, mais variable en intensité. Ainsi, chez ces trois espèces, on note une diminution de la proportion de femelles gestantes ou allaitantes au début de la grande saison sèche (juin-juillet). Un autre aspect de la reproduction concerne la taille des portées, dont il existe des variations inter-spécifiques. Cinq espèces murines ont des portées moyennes de 2 à 3 jeunes (*Heimyscus fumosus*, N = 4; *Hybomys univittatus*, N = 12; *Hylomyscus stella*, N = 9; *Praomys* sp. 1, N = 1 et *Praomys* sp. 2, N = 4). Par contre, les 2 femelles gestantes de *Deomys ferrugineus*

110

capturées portaient un seul embryon, et la femelle d'*Hylomyscus aeta* en portait 4. Pour une espèce donnée, la taille des portées peut varier: de 1 à 3 jeunes par portée pour *Hybomys univittatus*, 1 à 4 pour *Hylomyscus stella,* et 2 à 4 pour *Praomys* sp. 2.

Sex-ratios

Le sex-ratio obtenu est en faveur des mâles (test du Khi^2, P<0.01) pour *Hylomyscus stella* et *Praomys* sp. 2; tandis qu'il est équilibré pour *Deomys ferrugineus, Heimyscus fumosus, Hybomys univittatus* et *Praomys* sp. 1 (P>0.05).

Préférence écologique des espèces vis à vis du type d'habitat forestier

La richesse spécifique varie d'un type de forêt à l'autre (9 à 11 espèces, Fig. 1). Toutefois cette différence ne reflète pas forcément une réalité biologique. En effet, on constate que plus l'effort de piégeage est important, plus le nombre d'espèces capturé est grand; ceci est due à l'augmentation de la probabilité de capture des espèces rares telles que *Thamnomys rutilans*, *Hylomyscus aeta*, *H. parvus*, *Lophuromys nudicaudus* ou *Stochomys longicaudatus*.

Les densités relatives globales obtenues sont significativement plus élevées en forêt marécageuse (2.6%; P<0.01, $X^2 = 9.602$, ddl = 2). Par contre, elles sont comparables en forêt de terre ferme (1.9%) et en forêt ripicole (1.9%; P>0.05, $X^2 = 0.076$, ddl = 1). Les densités relatives de certaines espèces sont significativement différentes d'un type de forêt à l'autre (Fig. 1): *Hybomys univittatus* (P<0.001, $X^2 = 17.718$, ddl = 2) et *Heimyscus fumosus* (P<0.01, $X^2 = 9.567$, ddl = 2) préfèrent les sols de terre ferme, tandis que *Malacomys longipes* (P<0.001, $X^2 = 99.483$, ddl = 2) et *Praomys* sp. 2 (P<0.001, $X^2 = 21.324$ ddl = 2) préfèrent les sols hydromorphes. La densité relative de *Hylomyscus stella* (P>0.05, $X^2 = 4.438$, ddl = 2) et de *Praomys* sp. 1 (P>0.05, $X^2 = 3.369$, ddl = 2) ne sont pas significativement différente d'un habitat à l'autre.

Dans les 3 peuplements étudiés, *Hylomyscus stella* est l'espèce dominante. Concernant l'abondance relative des espèces, les peuplements de forêts ripicoles et marécageuses présentent le même profil. Il s'oppose en revanche à celui de forêt de terre ferme par l'abondance de *Malacomys longipes* et *Praomys* sp. 2 (plus abondants sur sols hydromorphes), et d'*Heimyscus fumosus* et *Hybomys univittatus* (plus abondants en terre ferme).

Nous avons montré qu'il existe des différences significatives de structure du peuplement Muridae entre les trois types d'habitats inventoriés. On se propose maintenant de comparer, pour un type d'habitat donné (la forêt de terre ferme), la structure et la dynamique des peuplements Muridae de 2 sites.

Analyse spatio-temporelle des peuplements Muridae en forêt de terre ferme

Comparaison de la composition et de la structure des peuplements des sites A et B

Les deux sites A et B présentent 11 espèces communes. Le site A est plus riche d'une espèce que le site B, en raison de la capture d'un spécimen de *Thamnomys rutilans*.

La densité relative globale est significativement supérieure sur B (2.5%) que sur A (1.3%; P<0.001, $X^2 = 80.72$, ddl = 1). Ceci est lié aux densités relatives plus élevées (seuil 0.05, ddl = 1) sur B que sur A de *Hybomys univittatus* (0.6% sur B et 0.2% sur A; $X^2 = 62.49$), *Praomys* sp. 1 (0.1 et 0.05%; $X^2 = 5.57$), *Praomys* sp. 2 (0.4 et 0.2%; $X^2 = 12.27$), et *Hylomyscus stella* (1.0 et 0.5%; $X^2 = 30.27$; Fig. 2).

Les abondances relatives de toutes les espèces sont bien corrélées entre les deux sites (P<0.001, n = 11, r = 0.899). En effet, tant en A qu'en B, *H. stella* est l'espèce
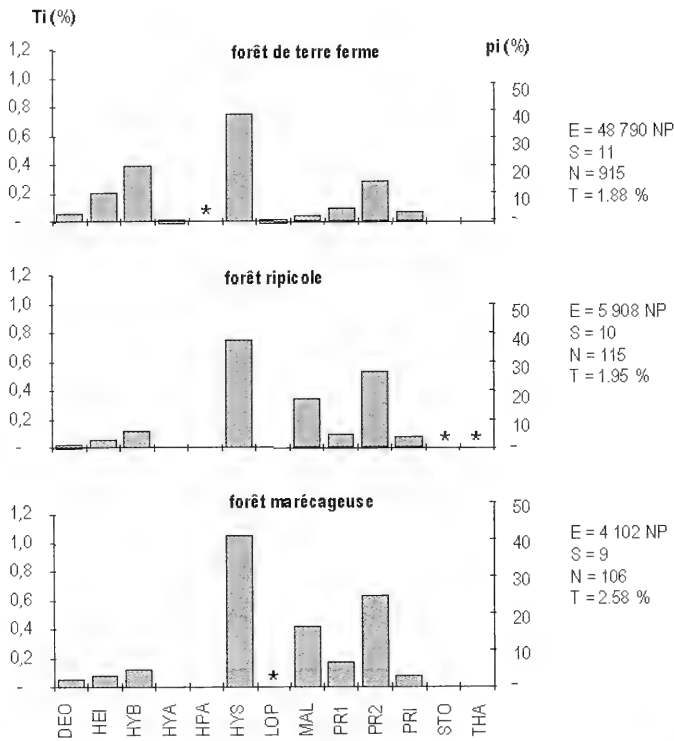
FIGURE 1. Densités relatives (Ti, %) et abondances relatives (pi, %) des 11 espèces de Muridae dans 3 types d'habitats forestiers. Les efforts (E, nuit.pièges), richesses spécifiques (S), effectifs (N) et densités relatives globales (T, %) sont indiqués à droite des graphiques. Le symbole * signifie que des spécimens ont uniquement été capturés en Pitfalls. DEO: *Deomys ferrugineus*, HEI: *Heimyscus fumosus*, HYB: *Hybomys univittatus*, HYA: *Hylomyscus aeta*, HPA: *H. parvus*, HYS: *H. stella*, LOP:*Lophuromys nudicaudus*, MAL: *Malacomys longipes*, PR1: *Praomys* sp. 1, PR2: *Praomys* sp. 2, PRI: *Praomys* sp, STO: *Stochomys longicaudatus*, THA: *Thamnomys rutilans*.

dominante (pi >40%), *Praomys* sp. 2, *Hybomys univittatus* et *Heimyscus fumosus* sont communes (9 à 25%), les autres espèces sont peu abondantes ou rares (<5%). L'abondance relative des espèces n'est pas corrélé à leur poids: sur les deux sites, c'est une espèce de faible poids (*Hylomyscus stella*) qui domine le peuplement.

La biomasse relative globale (P<0.001, $X^2 = 2030.14$, ddl = 1) est supérieure en B (69.6 g.%) qu'en A (33.8 g.%). Toutes les espèces n'étant pas de la même taille, sur les deux sites, la distribution des biomasses relatives spécifiques diffère de celle des abondances relatives. De plus, alors que sur le site B, en terme de biomasse, *Hybomys univittatus* domine le peuplement, sur A cette espèce codomine avec *Hylomyscus stella*.

Dynamique du peuplement Muridae sur chaque site d'étude
Site A

La richesse spécifique mensuelle du peuplement varie au cours de la période d'étude de 6 (juillet et septembre) à 9 (juin) espèces (Fig. 3). Ces variations s'expliquent par la capture aléatoire des espèces rares (*Hylomyscus aeta, H. parvus, Lophuromys nudicaudus, Malacomys longipes* et *Thamnomys rutilans*).

La densité relative mensuelle globale varie significativement dans le temps (P<0.01, $X^2 = 80.58$, ddl = 6): elle diminue progressivement d'avril (2.2%) à octobre (0.4%). Deux
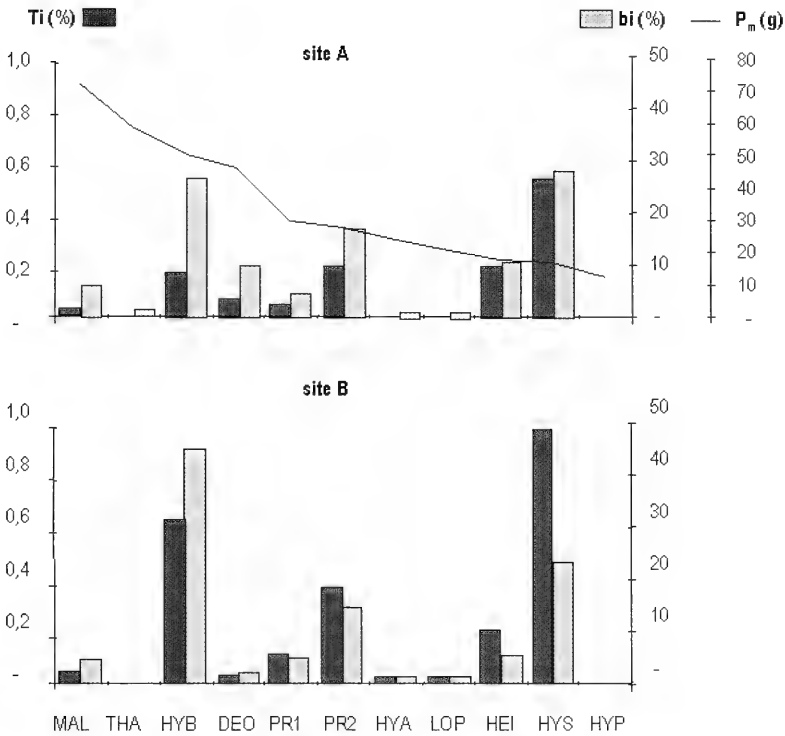
FIGURE 2. Densités relatives (Ti, %) et biomasses relatives (bi, %) des 11 espèces de Muridae sur les sites de forêt de terre ferme, A et B. Les espèces sont classées par ordre décroissant de poids moyen(P_m, g). Voir Fig. 1 pour la définition des acronymes.

pics de précipitations ayant eu lieu durant l'étude (l'un en avril-mai et l'autre en octobre), les variations de densité relative globale observées ne semblent pas corrélées à celles des précipitations. Les densités relatives mensuelles de trois des quatre espèces murines les plus abondantes (*Hylomyscus stella, Praomys* sp. 2 et *Heimyscus fumosus*) varient de façon significative dans le temps (P<0.01; X^2 = 51.22, 37.75, et 23.76 respectivement; ddl = 6; Fig. 4). Celle d'*Hylomyscus stella* est maximale en avril (1.1%), elle varie de 0.7 à 0.6% de mai à août et diminue ensuite progressivement jusqu'en octobre (0.1%); tandis que celle de *Praomys* sp. 2 augmente d'avril à juin (0.4 à 0.5%) puis diminue. Enfin, celle de *Heimyscus fumosus* augmente d'avril à août (0.04 à 0.3%), puis diminue les deux derniers mois (0.02% en octobre). La densité relative d'*Hybomys univittatus* ne varie pas significativement dans le temps (P>0.05; X^2 = 12.02; ddl = 6).

L'abondance relative des espèces varie d'un mois à l'autre. *Hylomyscus stella* est l'espèce dominante en avril, mai, juillet et août (37 à 52%). Elle codomine avec *Praomys* sp. 2 en juin (34 et 29% respectivement), et avec *Hybomys univittatus* en septembre (36 et 27%). Enfin, en octobre, *H. univittatus* devient l'espèce dominante (44%).
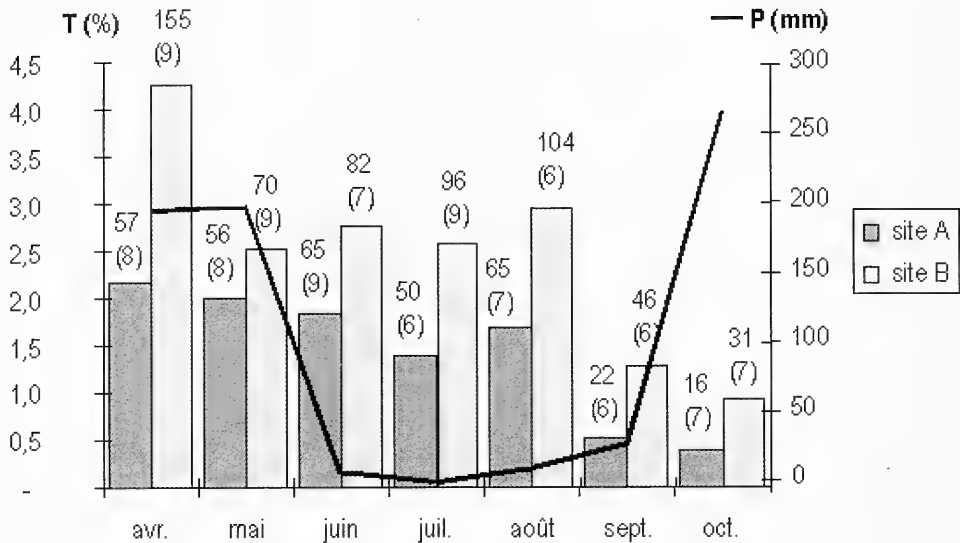
FIGURE 3. Densités relatives globales (T, %) des Muridae et précipitations (P, mm), d'avril à octobre 2000, sur les sites de forêt de terre ferme A et B. Au-dessus de chaque barre d'histogramme sont notés l'effectif brut (N) et la richesse spécifique (S), notée entre parenthèses.

Site B

Comme sur le site A, la richesse spécifique du peuplement varie au cours de la période d'étude de 6 à 9 espèces, respectivement en août-septembre et avril-mai (Fig. 3), en fonction des variations aléatoires de capture des espèces rares.

La densité relative mensuelle globale (Fig. 3) varie significativement dans le temps ($P<0.01$, $X^2 = 102.53$, ddl = 6). Elle est maximum en avril (4.3%), puis varie de 2.5 à 2.9% de mai à août, et diminue en septembre (1.3%) et octobre (0.9%). Les variations de densité relative globale observées ne semblent pas corrélées à celles des précipitations. Comme sur le site A, sur B, les densités relatives mensuelles de trois des quatre espèces murines les plus abondantes (*Hylomyscus stella, Praomys* sp. 2, et *Heimyscus fumosus*) varient de façon significative dans le temps ($P<0.01$; $X^2 = 39.57$, 71.10 et 31.57 respectivement; ddl = 6; Fig. 4). Celle d'*Hylomyscus stella* est maximale en avril (1.6%), elle varie de 1.0 à 1.2% de mai à août, et diminue ensuite progressivement jusqu'en octobre (0.3%). Celle de *Praomys* sp. 2 diminue d'avril (1.0%) à octobre (0.0%), avec cependant une légère augmentation en août (0.5%). La densité relative de *Heimyscus fumosus* varie de 0.4 à 0.6% de mai à juillet, et est inférieure à 0.1% le reste du temps. Enfin, la densité relative de *Hybomys univittatus* ne varie pas significativement durant les 7 mois de l'étude ($P>0.05$; $X^2 = 10.16$; ddl = 6).

On note également des variations d'abondance relative des espèces durant les 7 mois d'étude: *Hylomyscus stella* domine le peuplement d'avril à août (>37%); elle codomine avec *Hybomys univittatus* en septembre (43 et 41% respectivement); enfin, en octobre *Hybomys univittatus* devient l'espèce dominante (61%).
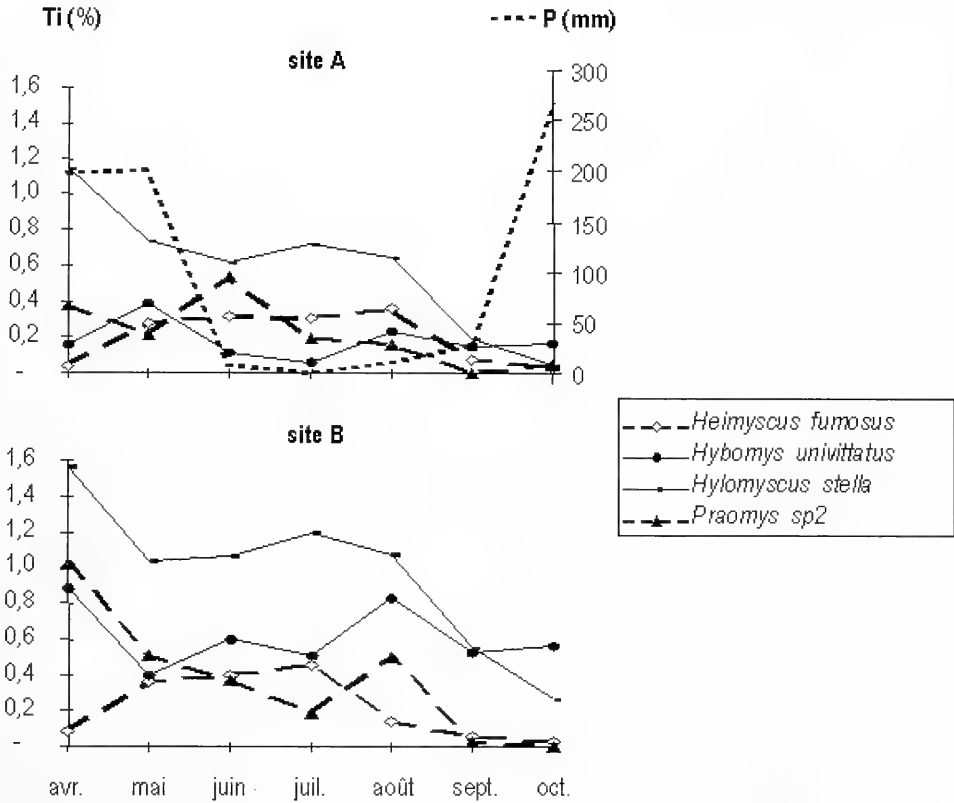
FIGURE 4. Densités relatives (Ti, %) des 4 espèces de Muridae les plus abondantes et précipitations (P, mm), d'avril à octobre 2000, sur les sites de forêt de terre ferme A et B.

Comparaison de la dynamique des peuplements Muridae des sites A et B

Les variations mensuelles de richesse spécifique ne sont pas synchrones entre les deux sites. Cependant, ces variations sont principalement dues à la capture aléatoire des espèces rares.

Les densités relatives mensuelles globales, bien que plus élevées sur B que sur A, présentent des variations temporelles similaires entre les deux sites d'étude. Cependant, bien que sur les deux sites se soient les mêmes espèces qui présentent ou non des variations temporelles de densité relative; ces variations ne semblent synchrones entre les deux sites que pour *Hylomyscus stella*. Enfin, quel que soit le mois, les densités relatives mensuelles de *H. stella*, *Hybomys univittatus*, et *Praomys* sp. 2 sont plus élevées sur B que sur A.

Les variations d'abondances relatives mensuelles observées sur les deux sites présentent des tendances communes: augmentation graduelle d'avril à octobre de celle *d'H. univittatus*; diminution de celle de *Praomys* sp. 2; *Hylomyscus stella*, bien qu'ayant une abondance relative mensuelle variable, reste d'avril à septembre l'espèce dominante ou codominante au sein du peuplement Muridae. Quelques différences peuvent cependant être notées concernant les variations d'abondances relatives mensuelles observées sur les deux

sites: de juin à août, *Hybomys univittatus* est la moins abondante des quatre espèces sur le site A, alors que ce n'est pas le cas sur le site B.

<center>SORICIDAE</center>

Tous sites et milieux confondus, 449 musaraignes ont été capturées en pièges Pitfalls, et 54 en Sherman-tapettes. Quatre genres et neuf espèces ont été recensés: *Crocidura batesi* (N = 55), *C. crenata* (N = 31), *C. dolichura* (N = 18), *C. goliath* (N = 25), *C. grassei* (N = 46), *Paracrocidura schoutedeni* (N = 68), *Suncus remyi* (N = 5), *Sylvisorex johnstoni* (N = 206) et *S. ollula* (N = 49). La méthode Pitfall, à la réussite de piégeage élevée (T = 4.45%), a permis de capturer les 9 espèces. Au contraire, la faible efficacité de capture des pièges Sherman-tapettes (T = 0.09%) n'a pas permis la capture des deux espèces de petite taille (*Suncus remyi* et *Sylvisorex johnstoni*). La réussite de piégeage en Pitfall est supérieure pour toutes les espèces.

Malgré la complexité taxinomique de cette sous-famille des Crocidurinae, la majorité des espèces échantillonnées, sur nos deux sites, est assez facilement identifiable à partir des caractères morpho-anatomiques. Seuls *Crocidura goliath* et *C. batesi*, appartenant à deux groupes complexes et nécessitant une révision taxinomique, posent quelques problèmes d'identification spécifique. Les spécimens de *C. goliath* capturés sont globalement de taille inférieure à ceux du Cameroun d'où l'espèce a été décrite. Les espèces *C. batesi* et *C. poensis* sont souvent confondues (Hutterer 1993) et une récente analyse phylogénétique (Quérouil, donnée non publiée) montre l'impossibilité de les distinguer sur base de séquences mitochondriales (ARNr 16S). Les spécimens appartenant à ce complexe, ont, dans cette étude, été attribués à l'espèce *C. batesi*, ce qui n'exclue pas la présence de *C. poensis*.

L'espèce pygmée *Sylvisorex johnstoni* domine largement le peuplement (41%), suivie de *Paracrocidura schoutedeni* (13%). Les espèces les plus rares sont *Suncus remyi* (1%) et *Crocidura dolichura* (4%).

Reproduction

L'activité reproductrice de *Sylvisorex johnstoni* semble effective pendant toute la période de suivi. Pour les autres espèces, les effectifs bruts de femelles, très variables d'un mois à l'autre et souvent nuls, ne permettent pas de conclure. La taille moyenne des portées varie de 1.4 à 1.8 embryons respectivement chez *S. johnstoni* (N = 15) et *Paracrocidura schoutedeni* (N = 5), à 3 et 3.5 embryons respectivement chez *Crocidura goliath* (N = 5) et *Sylvisorex ollula* (N = 4).

Sex-ratios

Trois espèces (*Crocidura batesi*, *C. crenata*, *Sylvisorex ollula*) ont un sex-ratio en faveur des mâles (test du Khi^2, P<0.005). Les autres espèces ont un sex-ratio équilibré (P>0.05).

Préférence écologique des espèces vis à vis du type d'habitat forestier

Le nombre d'espèces capturées en forêt de terre ferme, ripicoles et marécageuse sont respectivement de 9, 7 et 8 (Fig. 5). Les 7 espèces présentes en forêt ripicole le sont également dans les deux autres types d'habitat. *Suncus remyi* n'a, en revanche, été capturé qu'en terre ferme où l'effort de piégeage est le plus élevé. *Crocidura crenata* n'a fait l'objet d'aucune capture en forêt ripicole.

<center>116</center>
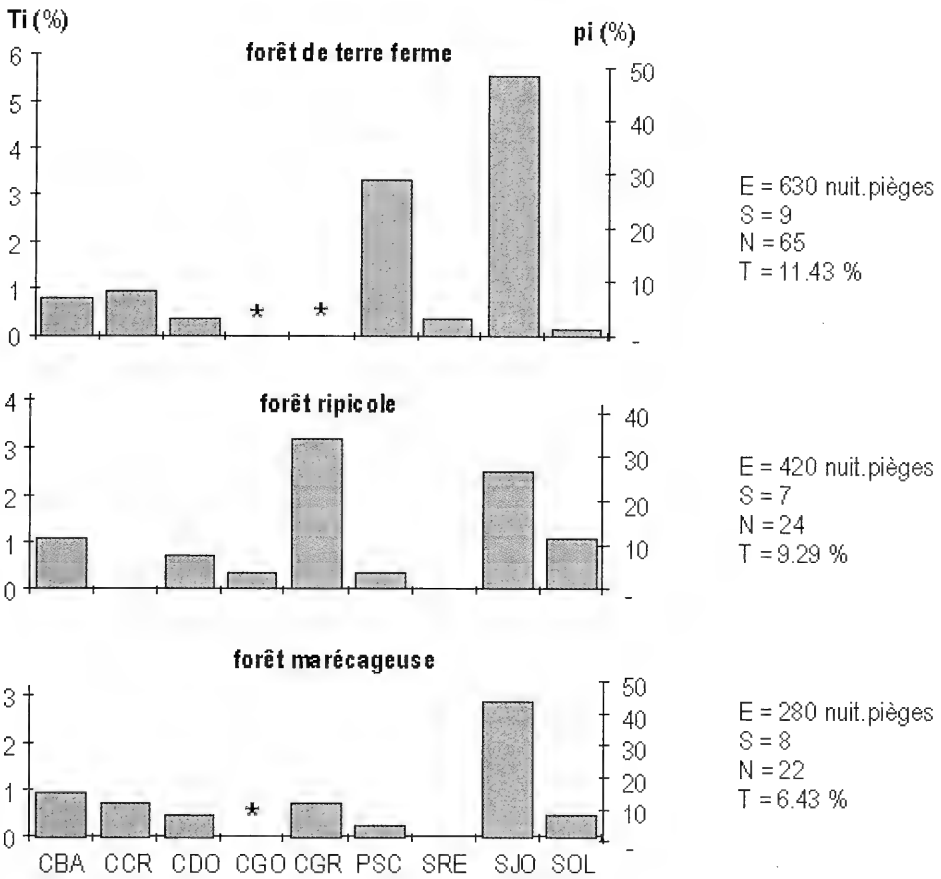
FIGURE 5. Densités relatives (Ti, %) et abondances relatives (pi, %) des 9 espèces de Soricidae dans 3 types d'habitat forestier. Les efforts (E, nuit.pièges), richesses spécifiques (S), effectifs (N) et densités relatives globales (T, %) sont indiqués à droite des graphiques. Le symbole * signifie que des spécimens ont uniquement été capturés en Sherman-tapettes. CBA: *Crocidura batesi*, CCR: *C. crenata*, CDO: *C. dolichura*, SGO: *C. goliath*, CGR: *C. grassei*, PSC: *P. schoutedeni*, SRE: *Suncus remyi*, SJO: *Sylvisorex johnstoni*, SOL: *S. ollula*.

La densité relative globale varie significativement entre habitats (P<0.05, ddl = 2, X^2 = 6.826): elle est maximale en terre ferme (11.4%) et minimale en forêt marécageuse (6.4%). Ceci est lié aux densités relatives de *Sylvisorex johnstoni* et *Paracrocidura schoutedeni* supérieures en terre ferme (5.6 et 3.3%) qu'en sols hydromorphes (2.5 et 0.4% respectivement en forêt ripicole; 2.9 et 0.2% en forêt marécageuse; P = 0.011, X2 = 9.15, ddl = 2; Fig. 5). Rare en terre ferme (0%), *Crocidura grassei* semble affectionner particulièrement les sols ripicoles (3.2%) et marécageux (0.7%).

Sylvisorex johnstoni est abondante dans les 3 types d'habitat (pi de 26 à 49%); à l'inverse, *Crocidura goliath* et *Suncus remyi* sont toujours rares (<3%) ou absents. L'abondance relative de la majorité des autres espèces varie d'un habitat à l'autre. *Crocidura grassei*, rare en terre ferme et commune en forêt marécageuse (11%), est

l'espèce dominante en forêt ripicole (34%). A l'inverse, *Paracrocidura schoutedeni* commune en terre ferme (29%) est rare en forêts hydromorphes (<4%).

Analyse spatio-temporelle des peuplements Soricidae en forêt de terre ferme

Comparaison de la composition et de la structure des peuplements des sites A et B

La richesse spécifique (9) et l'identité des espèces est identique sur les deux sites (Fig. 6).

La densité relative globale est significativement supérieure sur A (4.5%) que sur B (3.2%; P = 0.003, X^2 = 9.117, ddl = 1). Ceci est lié aux densités relatives plus élevées (seuil 0.05) sur A que sur B de *Crocidura batesi* (0.8 sur A et 0.1% sur B; P<0.01; X^2 = 18.908, ddl = 1), *Paracrocidura schoutedeni* (0.8 et 0.3%; P = 0.003; X^2 = 8.840, ddl = 1) et *Sylvisorex ollula* (0.6% et 0.3%; P = 0.013; X^2 = 6.208, ddl = 1).

La structure du peuplement varie d'un site à l'autre (seuil 0.05, n = 9, Spearman, r = 0.661). Ainsi, bien que *S. johnstoni* soit l'espèce dominante sur les deux sites (pi = 41 et 54% respectivement sur A et B), tandis que *Crocidura dolichura* (3 et 4%), *C. goliath* (1 et 2%), *C. grassei* (1 et 6%) et *Suncus remyi* (1%) sont rares; en revanche, l'abondance relative des autres espèces varie d'un site à l'autre. Ainsi, *Crocidura batesi, P. schoutdeni* et *Sylvisorex ollula* sont plus abondants sur A que sur B; tandis que c'est le cas inverse pour *Crocidura crenata*.

Comme la densité relative globale, la biomasse relative globale est supérieure sur le site A (35.2%) que sur le site B (20.1%). Etant donné les différences de taille entre les espèces la distribution des biomasses relatives spécifiques diffère de celle des abondances relatives. De plus, alors que sur le site A les deux espèces dominantes, en terme de biomasse relative, sont *C. batesi* et *Sylvisorex ollula*, en revanche sur le site B *Sylvisorex johnstoni* est dominante.

Dynamique du peuplement Soricidae sur chaque site d'étude

Site A

D'avril à octobre, la richesse du peuplement A varie de 8 à 3 espèces (Fig. 7). Seulement 3 espèces furent collectées en octobre, mois pendant lequel l'effort de piégeage était inférieur (105 nuit.pièges) aux mois précédents. Seule l'espèce dominante *Sylvisorex johnstoni* a été capturé en Pitfall tout au long de la période d'échantillonnage.

La densité relative globale varie significativement d'un mois à l'autre (P<0.01, ddl = 6, X^2 = 57.4). Elle est maximale en petite saison des pluies (mai: 9.7%), et minimale en grande saison sèche (juillet: 1.4%). Bien que les variations de richesse spécifique et de densité relative globale ne soient pas significativement corrélées à celles de la pluviométrie, ces variables évoluent globalement dans le même sens. Les variations temporelles de densité relative globale sont principalement conditionnées par la dynamique des quatre espèces les plus abondantes: *S. johnstoni, S. ollula, Crocidura batesi*, et *Paracrocidura schoutedeni*. Bien que ces variations mensuelles soient significatives (P = 0.001, X^2 = 22.147, ddl = 6) et suivent globalement la pluviométrie, aucune synchronie n'apparaît ni entre les espèces ni avec la pluviométrie (Fig. 8). *Sylvisorex johnstoni* est l'espèce pour laquelle les variations mensuelles de densité relative sont les plus marquées, avec une diminution progressive d'avril (3.8%) à août (0.6%) puis une augmentation jusqu'en octobre (1.9%).

Pendant tout la période d'étude, *S. johnstoni* reste globalement dominante (pi = 23 à 67%). En revanche, les abondances relatives de *Crocidura batesi, Sylvisorex ollula* et
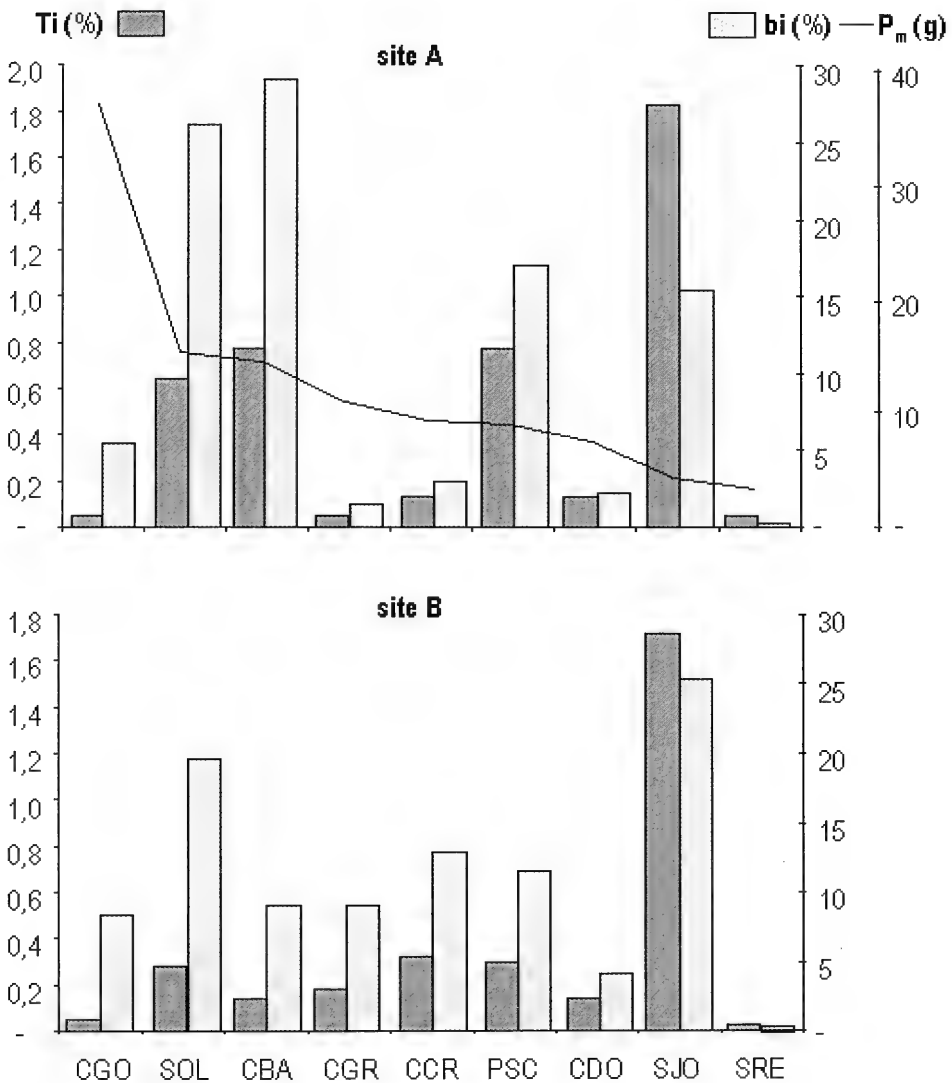
FIGURE 6. Densités relatives (Ti, %) et biomasses relatives (bi, %) des 9 espèces de Soricidae sur les sites de forêt de terre ferme A et B. Les espèces sont classées par ordre décroissant de poids moyen (P_m, g). Voir Fig. 5 pour la définition des acronymes.

Paracrocidura schoutedeni varient de façon importante, et chacune d'elle n'a alors pas la même importance numérique au sein du peuplement.

Site B

La richesse du peuplement B varie de 4 à 9 espèces d'avril à octobre (Fig. 7). L'espèce dominante (*Sylvisorex johnstoni*) est la seule à avoir été collectée chaque mois sur ce site.
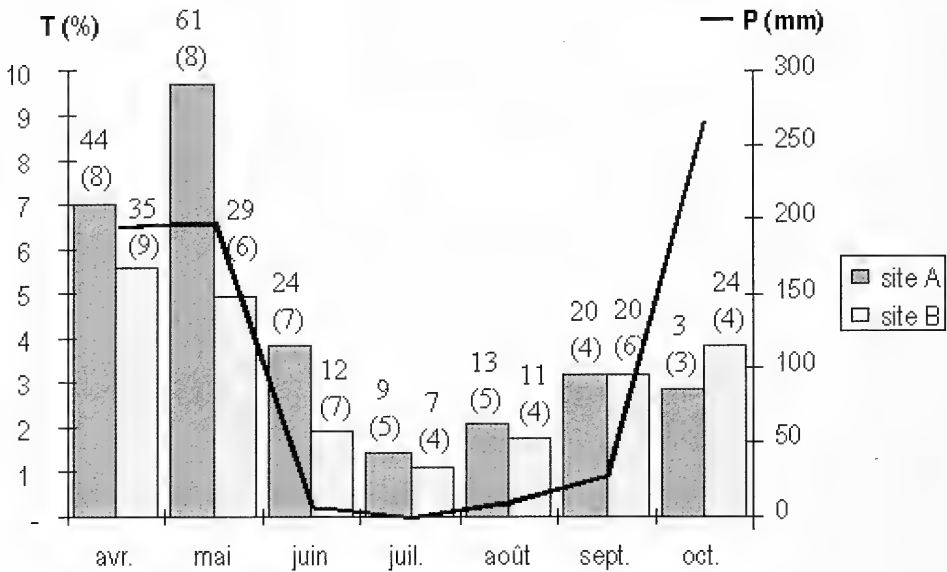
FIGURE 7. Densités relatives globales (T, %) des Soricidae et précipitations (P, mm), d'avril à octobre 2000, sur les sites de forêt de terre ferme A et B. Au-dessus de chaque barre d'histogramme sont notés l'effectif brut (N) et la richesse spécifique (S), notée entre parenthèses.

La densité relative globale mensuelle varie significativement (P<0.01, ddl = 6, X^2 = 32.5): elle diminue progressivement d'avril à juillet (5.6 à 1.1%), puis augmente progressivement jusqu'en octobre (3.8%); suivant globalement la dynamique des pluies. Cependant, cette dynamique n'est principalement attribuable qu'aux variations de densité relative de *S. johnstoni* (P = 0.006, X^2 = 18.344, ddl = 6; Fig. 8). La densité relative de cette espèce est maximale en avril-mai (2.7 et 2.9%), reste faible durant la grande saison sèche de juin à septembre (0.8 à 1.1%) et augmente à nouveau en octobre (2.5%).

Dominante durant toute la période (35 à 71%), *S. johnstoni* codomine au mois de septembre, en fin de saison sèche, avec *S. ollula* (30%; Fig. 8). L'abondance relative de *Paracrocidura schoutedeni* augmente légèrement en juin (25%) et en août (18%). Les abondances relatives des espèces les plus rares sont trop faibles pour dessiner une dynamique observable.

Comparaison de la dynamique des peuplements Soricidae des sites A et B

Sur les deux sites, les richesses spécifiques, densités relatives globales et densité relative de *Sylvisorex johnstoni* sont maximales en petite saison des pluies et minimales en grande saison sèche. Les seules informations concordantes entre les deux sites, en terme de variations mensuelles d'abondance relative, sont la dominance de *Sylvisorex johnstoni* tout au long de la période d'étude et le pic de *S. ollula* en septembre, à la fin de la grande saison sèche.
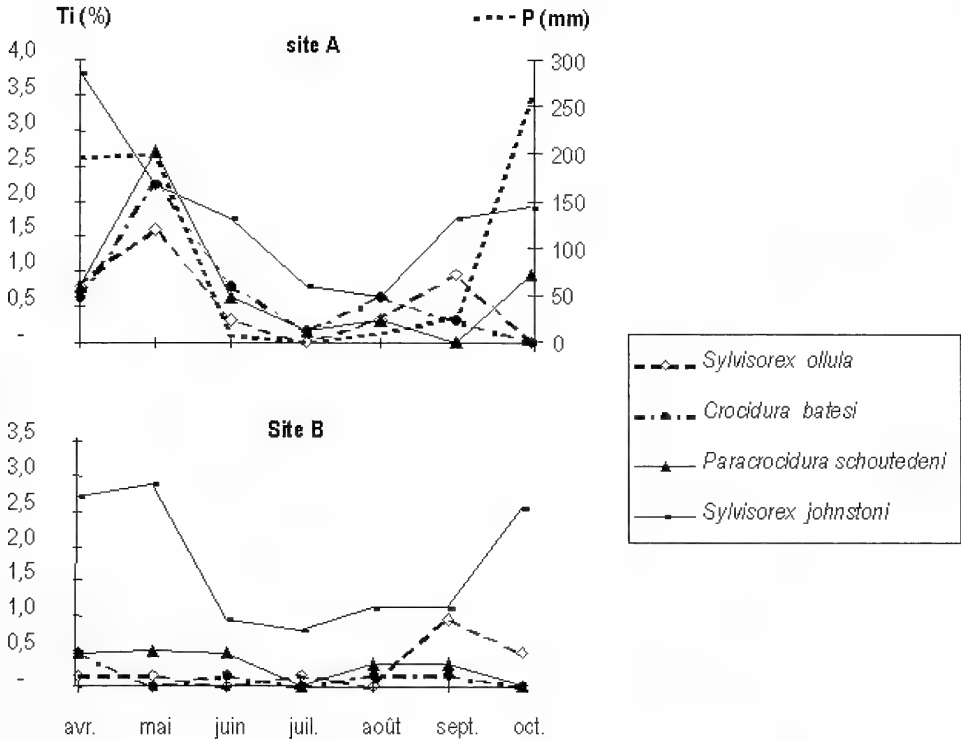
FIGURE 8. Densités relatives (Ti, %) des 4 espèces de Soricidae les plus abondantes et précipitations (P, mm), d'avril à octobre 2000, sur les sites de forêt de terre ferme A et B.

DISCUSSION

Inventaire et positionnement biogéographique des Monts Doudou en Afrique ouest-centrale

Les 9 genres de Muridae et les 4 genres de Soricidae présents sur nos sites se retrouvent également sur la majorité des peuplements forestiers étudiés en Afrique ouest-centrale: Gabon (Duplantier 1982; Brosset 1988; Goodman et al. 2001), Guinée équatoriale (Lasso 1995; Lasso et al. 1996), République du Congo -RC- (Granjon 1991; Colyn et al. 1996), Cameroun (Hutterer et Schlitter 1996, Colyn et al. 1996), et République centrafricaine -RCA- (Petter et Genest 1970; Ray et Hutterer 1995). Seuls quelques secteurs de RCA (Barrière et Nicolas 2000) et de RC (Barrière 1997b; Hutterer et al. 2001) présentent un genre supplémentaire de musaraigne (*Congosorex*). Le muridé du genre *Prionomys* n'a, quant à lui, été capturé que dans quelques sites du Cameroun (Dollman 1910), de la RCA (Petter et Genest 1970) et de la RC (Denys, comm. pers.).

Les études précédentes réalisées sur les Muridae des forêts planitiaires d'Afrique ouest-centrale dénombraient 9 à 13 espèces selon les sites (Petter et Genest 1970; Duplantier 1982; Granjon 1991; Lasso 1995; Nicolas et Barrière 2001). Les 12 espèces murines que nous avons capturées, sont typiques de ces forêts. En effet, elles ont également été inventoriées dans la majorité des sites forestiers précédemment échantillonnées. *Prionomys*

121

batesi et *Praomys jacksoni*, précédemment capturés en Afrique ouest-centrale (Dollman 1910; Petter et Genest 1970; Granjon 1991) sont absentes de notre inventaire. Ces espèces semblent préférer les zones situées à l'écotone forêt/savane et/ou secondarisées; il se peut donc qu'elles soient présentes dans la région des Monts Doudou, mais que nous ne les ayons pas capturées, puisque nos piégeages ont eu lieu au cœur du massif forestier. Les autres différences, en terme d'identité des espèces, observées par rapport aux études antérieures, concernent des espèces difficilement identifiables et dont la position taxinomique est en cours de révision (majorité des espèces des genres *Praomys* et *Hylomyscus*). Il est donc probable que les différences obtenues ne reflètent pas une réalité biologique, mais plutôt des problèmes d'identification. Soulignons la rareté, dans les Monts Doudou, de *Stochomys longicaudatus* (1 seul spécimen sur 1198) comparé aux autres régions d'Afrique ouest centrale (Colyn et al. 1996).

La richesse spécifique soricine (9 espèces) obtenue est, quant à elle, largement inférieure aux valeurs maximales de 16 et 18 trouvées jusqu'alors sur deux sites forestiers de RCA respectivement par Ray et Hutterer (1995) et Barrière et Nicolas (2000). Cette valeur ne s'éloigne cependant guère de la majorité des sites inventoriés en Guinée équatoriale (Lasso et al. 1996: 8 espèces), au Cameroun (Hutterer et Schlitter 1996: 9; Barrière 1997b: 10) et en RC (Barrière 1997b: 10 à 13). Au Gabon, 3 études distinctes révèlent une richesse identique de 11 espèces à Belinga-Makokou (Brosset 1988), en forêt des Abeilles (donnée non publiée) et en forêt de Minkébé (Goodman et al. 2001), avec cependant des différences en terme d'identité spécifique. *Crocidura olivieri* n'a été capturée qu'à Belinga-Makokou et en forêt des Abeilles (donnée non publiée), tandis que *C. maurisca* ne l'a été qu'à Minkébé. Brosset (1966) note également à Belinga la présence d'une espèce très rare, *C. wimmeri*, auparavant localisée sur la côte ivoirienne. Il serait donc envisageable que certaines espèces rares (*C. wimmeri*, *C. nigrofusca*) ou difficiles à identifier (*C. mutesae, C. olivieri, C. poensis*) n'aient pas pu être reconnues à ce jour.

Remarquons enfin, que les savanes arbustives situées en périphérie du massif et les zones de forêt secondarisées pourraient révéler la présence d'espèces supplémentaires. Ainsi, *Lemniscomys striatus, Pelomys campanae, Mastomys* sp., *Leggada* sp., *Dasymys incomtus, Lophuromys sikapusi* ou *Oenomys hypoxanthus* ont été capturés dans le bassin du Kouilou (Granjon 1991) et/ou en périphérie des Monts Doudou. De même, pour les soricidés, les collectes effectuées par notre laboratoire dans des îlots de savane de la forêt des Abeilles (1995) et dans la savane du piémont des Monts Doudou (2001), révéleraient la présence de espèces du complexe *Crocidura hildegardeae* (donnée non publiée).

L'abondance relative et l'identité des espèces abondantes ou rares est semblable avec de nombreuses études de communautés de l'Afrique ouest centrale. Notre étude n'ayant révélé, à ce jour, aucune espèce à distribution localisée, la région des Monts Doudou ne semble pas constituer, pour les micro-mammifères, un centre d'endémisme. L'intérêt du site réside cependant dans le fait qu'il abrite plusieurs espèces à large distribution mais généralement rares ailleurs comme *C. goliath, C. grassei, C. batesi* et *Suncus remyi*.

Sex-ratios

Le sex-ratio de la majorité des espèces murines dévie peu de un, ce qui est conforme aux données de Duplantier (1982) pour le Nord-est du Gabon, et de Dudu (1991) pour la République Démocratique du Congo. A l'inverse, le sex-ratio de trois des neuf espèces de Soricidés est en faveur des mâles. Sur différents autres sites de l'Afrique ouest centrale, nous avons également remarqué que le sex-ratio des musaraignes est souvent en faveur des mâles.

Préférences écologiques

Alors que la richesse spécifique des Muridés est similaire dans les trois types d'habitat forestier (terre ferme, ripicole et marécageux), elle est en revanche supérieure en forêt de terre ferme pour les soricidés. Une richesse minimale en forêt marécageuse s'oppose aux observations de Dieterlen et Heim de Balsac (1979) observant la plus grande diversité de peuplement Soricidae en milieu humide.

La densité relative globale des Muridae est plus importante en forêt marécageuse, contrairement à celle des Soricidae qui l'est en forêt de terre ferme.

Les milieux hydromorphes, constamment inondés, présenteraient des ressources trophiques moins importantes et moins variées laissant moins de chance de survie aux musaraignes moins généralistes (Brosset 1988). De plus, la stricte terrestrialité de certaines espèces sans adaptations à la vie arboricole, comme c'est le cas de rares espèces de musaraignes africaines (Vogel 1974), ne leur permet pas d'échapper à l'eau environnante en grimpant sur la végétation. C'est le cas notamment de *Suncus remyi*, espèce de petite taille ayant une amplitude de tailles de proies réduite et un lien étroit avec la litière forestière. Autant pour *Sylvisorex johnstoni* que *Paracrocidura schoutedeni*, la non-adaptation aux milieux inondés en permanence explique la diminution de leur densité relative dans ces derniers, comme l'avait noté Heim de Balsac (1959) pour cette dernière espèce. Au contraire, un degré supérieur d'adaptation à l'arboricolie de *Crocidura grassei*, espèce plus "gracile" (Brosset, 1988), qui évite ainsi la compétition avec les autres espèces moins abondantes, expliquerait son statut dominant en forêt inondable.

La distribution des espèces murines en fonction du type de forêt pourrait être liée à leurs capacités de nage. En effet, alors que *Malacomys longipes*, *Praomys* sp. 1, *Praomys* sp. 2 et *Hylomyscus stella* nagent bien, cela n'est pas le cas de *Hybomys univittatus* et *Heimyscus fumosus* (données non publiées). La préférence de *Malacomys longipes* pour les sols hydromorphes est déjà connue; Kerbis Peterhans et Patterson (1995) soulignent d'ailleurs que ce muridé utilise son pied, en forme d'échasse, pour se déplacer en eaux peu profondes. L'ubiquité du genre *Hylomyscus* vis à vis de l'habitat a, quant à elle, déjà été souligné par Duplantier (1982).

Variabilité spatio-temporelle des peuplements en forêt de terre ferme
Comparaison de la composition et de la structure des peuplements des sites A et B

Les richesses spécifiques des micro-mammifères obtenues sur les 2 sites de forêt de terre ferme sont similaires. En revanche, les densités et biomasses relatives globales varient significativement d'un site à l'autre: elles sont supérieures sur le site B pour les Muridae, et inversement pour les Soricidae. Ces différences sont relativement importantes dans la mesure où l'on observe des différences du même ordre entre peuplements de régions ou de pays distincts (Nicolas 1999; Barrière et Nicolas 2000). Les abondances relatives des Muridae sont comparables entre les deux sites. En revanche, pour les Soricidae, bien que *Sylvisorex johnstoni* soit dominante sur les deux sites ceci est plus marqué sur B. Les biomasses relatives spécifiques diffèrent d'un site un l'autre, tant pour les Muridae que les Soricidae.

Soulignons que chez les soricidés l'espèce la plus abondante (*S. johnstoni*) est celle dont la taille moyenne des portées est la plus faible. L'abondance des espèces de soricidés ne semble donc pas liée à la taille de leurs portées.

Variations temporelles

Alors que les variations mensuelles de richesse spécifique des Muridés semblent liées à la capture aléatoire des espèces rares; la diversité des peuplements soricidés semble étroitement liée à la pluviométrie. Ces observations sont en accord avec celles de Duplantier (1982) sur les Muridae, et celles de Lasso et al. (1996) et Barrière et Nicolas (2000) sur les Soricidae.

A l'instar des études antérieures menées en Afrique tropicale (Dosso 1983; Duplantier 1982; Barrière et Nicolas 2000), on note des fluctuations temporelles de densité des micro-mammifères, qui sont plus ou moins marquées selon les espèces. Cependant, ces variations ne sont pas toujours synchrones, pour une espèce donnée, entre les deux sites d'étude.

Chez les muridés, seules les variations de densités relatives de *Hylomyscus stella* sont synchrones entre les deux sites d'étude. Ces variations temporelles seraient issues de la combinaison de la dynamique des facteurs extrinsèques (météorologiques, climatologiques, phénologiques) et de celle des facteurs écologiques intrinsèques des espèces mammaliennes étudiées. Selon la littérature, la reproduction des muridés, bien qu'ayant lieu toute l'année, présente un pic lié au cycle saisonnier des pluies (Dubost 1968; Duplantier 1982, Dosso 1983): les maxima de reproduction coïncideraient, pour de nombreuses espèces, avec les périodes pluvieuses. Les changements saisonniers des précipitations se répercutent sur la biomasse, le couvert et la hauteur de la végétation, ainsi que sur l'abondance des ressources trophiques; paramètres qui influenceraient la reproduction des muridés (Taylor et Green 1976; Happold 1977). Chez *Hybomys univittatus*, *Hylomyscus stella* et *Praomys* sp. 2 nous observons une reproduction continue durant la période d'étude, avec cependant une diminution en début de grande saison sèche (juin-juillet). Ces résultats semblent donc confirmer les données de la littérature.

A ce jour, les études à long terme de la dynamique des population-peuplements Soricidae en Afrique tropicale sont insuffisantes pour que nous puissions avoir une base de données adaptée nous permettant de faire des comparaisons temporelles pour chaque espèce. Dans les Monts Doudou, la densité relative de *Sylvisorex johnstoni* est maximale en petite saison des pluies et minimale en grande saison sèche. Diverses études montrent que les musaraignes ont un métabolisme très élevé entraînant des pertes hydriques et énergétiques importantes d'où un besoin vital de s'alimenter régulièrement (synthèse, Barrière 1997a), et que l'humidité est un facteur déterminant pour l'abondance et la diversité des insectivores et de leurs proies (Churchfield 1990). Puisqu'il existe des variations saisonnières d'humidité en forêt tropicale, et que certaines espèces sont capables d'entrer en torpeur lorsque les conditions climatiques sont défavorables (Rychlik 1998), les variations apparentes de densité relative pourraient être liées à des variations d'activité locomotrice des espèces (donc leur risque de tomber dans un seau) et non à de réelles variations d'effectifs.

En conclusion, on observe des différences de densité, de biomasse et d'abondances relatives d'un site à l'autre au sein des forêts de terre ferme. Ces différences restent, à ce jour, inexpliquées. Quels que soient les facteurs écologiques responsables de ces variations, l'interprétation de résultats d'inventaires doit à la fois tenir compte (i) de l'effort de piégeage mis en place, puisque certaines espèces sont localement rares (ex: 1 *Stochomys longicaudatus* capturé pour un effort total de 60950 nuit.pièges), (ii) des types d'habitats et micro-habitats échantillonnés, (iii) de la variabilité spatiale et (iv) des variations temporelles de composition et structure de communautés.

Puisque la valeur maximale de densité d'une des deux communautés s'oppose à la valeur minimale de l'autre, autant entre habitats différents qu'entre deux sites de terre

ferme, ne pourrait-on pas suggérer l'existence de relations compétitives entre ces deux peuplements?

En terme de biodiversité, il ressort de notre étude, qu'une faible superficie (2 km²) de forêt planitiaire, peut abriter la majorité des espèces forestières murines présentes en Afrique ouest centrale. Contrairement aux résultats des inventaires dirigés sur d'autres groupes taxinomiques tels que les primates et les céphalophes (Colyn, de cet ouvrage), les deux peuplements concernés ne semblent pas renfermer d'espèce endémique aux forêts Sud-Ngounié, ni même au bloc forestier Sud-Ogooué. A l'inverse, on y note la présence d'espèces à large distribution, parfois rares ailleurs comme *Crocidura goliath*, *C. grassei*, *C. batesi* et *Suncus remyi*. De plus, ces quatre espèces semblent bien représentées dans les Monts Doudou, puisque collectées sur au moins 2 des 3 localités situées à 110, 375 et 625 m d'altitude (Goodman et Hutterer, de cet ouvrage). L'absence de taxon endémique dans un ou plusieurs groupes taxinomiques ne remet pas nécessairement en question le fait que cette région appartienne ou non à une Unité Faunique caractérisée et/ou un Refuge Forestier du Quaternaire supérieur (Colyn, de cet ouvrage). Cependant, la présence de plusieurs espèces forestières réputées rares semble indiquer que la région concernée ne correspond pas à une zone de dispersion. Ces éléments nous conduisent à confirmer que la zone forestière des Monts Doudou est l'un des pôles constituant le Refuge Forestier "Sud Ogooué" (Colyn, de cet ouvrage). Par ailleurs, si la région délimitée pour la zone d'étude (Réserve de la Moukalaba) ne semble pas renfermer d'espèces montagnardes telles que celles observées dans les hautes terres du Cameroun; en revanche, les plaines savanicoles du piedmont renferment des espèces telles que *Pelomys campanae* qui témoignent d'échanges récents (holocène) avec les savanes zambiennes au sud du fleuve Congo.

BIBLIOGRAPHIE

BARRIÈRE, P. 1997a. Approche de l'écologie des Soricidae forestiers tropicaux africains. DEA, Rapport bibliographique, Université de Rennes, France. 20 pp.

————. 1997b. Ecologie des Peuplements de Soricidae Forestiers d'Afrique Centrale: considérations nouvelles sur base de la méthode de piégeage Pitfall. DEA, Rapport de stage de recherche, Université de Rennes, France. 34 pp.

BARRIÈRE, P. AND V. NICOLAS. 2000. Rapport d'expertise sur le biodiversité animale en forêt de Ngotto (RCA): écologie et structuration des peuplements de micro-mammifères: musaraignes et rongeurs. Rapport ECOFAC-CEE, AGRECO-CTFT. 55 pp.

BROSSET, A. 1966. Recherches sur la composition qualitative et quantitative des populations de vertébrés dans la forêt primaire du Gabon. Biol. Gab. 2:163–177.

————. 1988. Le peuplement de Mammifères insectivores des forêts de nord-est du Gabon. Rev. Ecol. -Terre Vie 43:23–46.

BROSSET, A., G. DUBOST, AND H. HEIM DE BALSAC. 1965. Mammifères inédits récoltés au Gabon. Biol. Gab. 1:147–174.

CHURCHFIELD, S. 1990. The natural history of shrews. Christopher Helm, London. 175 pp.

COLYN, M., D. CORNELIS, AND O. PERPETE. 1996. Synthèse "Micro-mammifères" Muridae et Soricidae. Structure des peuplements: richesse et diversité spécifiques et indices d'abondance. Projet ECOFAC-CEE, AGRECO-CTFT.

DENYS, C., J. C. GAUTUN, M. TRANIER, AND V. VOLOBOUEV. 1994. Evolution of the genus *Acomys* (Rodentia: Muridae) from dental and chromosomal patterns. Israel J. Zool. 40:215–246.

DIETERLEN, V. F. AND H. HEIM DE BALSAC. 1979. Zur okologie und taxonomie der spitzmause (Soricidae) des Kivu-Gebietes. Säugetierk. Mitt. 27:241–287.

DOLLMAN, G. 1910. Two new African mammals. Ann. Mag. Nat. Hist. Ser.8, 6:226–230.

DOSSO, H. 1983. Etude des rongeurs de forêts hygrophiles conservées et de zones anthropisées de la côte d'Ivoire méridionale. Thèse, Université Nationale de Côte-d'Ivoire, Côte-d'Ivoire. 217 pp.

DUBOST, G. 1968. Aperçu sur le rythme annuel de reproduction des Muridés du nord-est du Gabon. Biol. Gab. 4:227–239.

DUDU, A. M. 1991. Etude du peuplement d'insectivores et rongeurs de la forêt ombrophile de basse altitude du Zaïre (Kisangani, Masako). Thèse, Université d'Anvers, Belgique. 171 pp.

DUPLANTIER, J. M. 1982. Les rongeurs myomorphes forestiers du nord-est du Gabon: peuplements, utilisation de l'espace et des ressources alimentaires, rôle dans la dispersion et la germination des graines. Thèse, Université des Sciences et des techniques du Languedoc, Montpellier, France. 129 pp.

GOODMAN, S. M., R. HUTTERER, AND P. R. NGNEGEU. 2001. A report on the community of shrews (Mammalia: Soricidae) occuring in the Minkebe Forest, northeastern Gabon. Mammalian Biology 66:223–234.

GRANJON, L. 1991. Les Rongeurs Myomorphes du bassin de Kouilou (Congo). *In* Flore et Faune du bassin du Kouilou (Congo) et leur exploitation. Tauraco Research Report 4:265–289.

HAPPOLD, C. D. C. 1977. A population study on small rodents in the tropical rain forest of Nigeria. Rev. Ecol -Terre Vie 31:385–458.

HEIM DE BALSAC, H. 1959. Premières données sur la répartition générale, l'écologie et la variation morphologique du genre *Paracrocidura* Heim de Balsac en Afrique Centrale (Mammifères Insectivores Soricidae). Rev. Zool. Bot. Afr. 54:19–28.

HUTTERER, R. 1993. Order Insectivora. Pp. 69–130 *in* Mammal Species of the World: a Taxonomic and Geographic Reference, 2nd edition, D. E. Wilson and D. M. Reeder, eds. Smithsonian Institution Press, Washington, D.C.

HUTTERER, R., P. BARRIÈRE, AND M. COLYN. 2001. A new myosoricine shrew from the Congo basin referable to the forgotten genus *Congosorex* (Mammalia: Soricidae). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 71(Suppl.):7–16.

HUTTERER, R. AND A. SCHLITTER. 1996. Shrews of Korup National Park, Cameroon, with the description of a new *Sylvisorex* (Mammalia: Soricidae). Contributions in Mammology, Museum of Texas Tech. University 57–66.

KERBIS PETERHANS, J. C. AND B. D. PATTERSON. 1995. The Ethiopian water mouse *Nilopegamys* Osgood, with comments on semi-aquatic adaptations in African Muridae. Zool. J. Linn. Soc. 113:329–349.

LASSO, C. 1995. Biodiversidad animal del Parque Nacional de Monte Alen. Programme ECOFAC-CEE, AGRECO-CTFT. 78 pp.

LASSO, C., R. HUTTERER, AND A. RIAL. 1996. Records of shrews (Soricidae) from Equatorial Guinea, especially from Monte Alen National Park. Mammalia 60:69–76.

MADDALENA, T. 1990. Systematics and biogeography of Afrotropical and Paleartic shrews of the genus *Crocidura* (Insectivora: Soricidae): an electrophoretic approach. Pp. 297–308 *in* Vertebrates in the Tropics, G. Peters and R. Hutterer, eds. Museum Alexander Koenig, Bonn, Allemagne.

MADDALENA, T. AND M. RUEDI. 1994. Chromosomal evolution in the genus *Crocidura* (Soricidae, Insectivora). Pp. 335–344 *in* Advances in the Biology of Shrews, J. F. Merritt, G. L. Kirkland, Jr, and R. K. Rose, eds. Carnegie. Mus. Nat. Hist. Spec. Publ. 18.

NEAL, B. R. AND A. G. COCK. 1969. An analysis of the selection of small African mammals by two break-back traps. J. Zool. Lond. 158:335–340.

NICOLAS, V. 1999. Les muridae forestiers d'Afrique tropicale: distinction des espèces du genre *Praomys* et caractérisation préliminaire des communautés. Rapport de DEA, Université de Rennes. 32 pp.

NICOLAS, V. AND P. BARRIÈRE. 2001. Diversité biologique du Refuge Forestier Pléistocène des Monts Doudou (Gabon). Rapport WWF. 87 pp.

PETTER, F. AND H. GENEST. 1970. Liste préliminaire des rongeurs myomorphes de République Centrafricaine. Description de deux souris nouvelles: *Mus oubangui* et *Mus goundae*. Mammalia 34:451–458.

QUÉROUIL, S., R. HUTTERER, P. BARRIÈRE, M. COLYN, J. C. KERBIS PETERHANS, AND E. VERHEYEN. 2001. Phylogeny and evolution of African Shrews (Mammalia: Soricidae) inferred from 16s rRNA sequences. Mol. Phylog. Evol. 20(2):185–195.

QUMSIYEH, M. B., S. W. KING, J. ARROYO-CABRALES, I. R. AGGUNDEY, D. A. SCHLITTER, R. J. BAKER, AND J. K. MARROW. 1990. Chromosomal and protein evolution in morphologically similar species of *Praomys sensus lato* (Rodentia, Muridae). J. Hered. 81:58–65.

RAY, J. C. AND R. HUTTERER. 1995. Structure of a shrew community in the Central African Republic based on the analysis of carnivora scats, with the description of a new *Sylvisorex* (Mammalia: Soricidae). Ecotropica 1:85–97.

RYCHLIK, L. 1998. Evolution of social systems in shrews. Pp. 347–392 *in* Evolution of shrews, J. M. Wojcik and M. Wolsan, eds. Mammal research institute, Polish academy of sciences, Białowieza.

SCHLITTER, D. A., R. HUTTERER, T. MADDALENA, AND L.W. ROBBINS. 1999. New karyotypes of shrews (Mammalia: Soricidae) from Cameroon and Somalia. Ann. Carnegie Mus. 68:1–14.

TAYLOR, K. D. AND M. G. GREEN. 1976. The influence of rainfall on diet and reproduction in four African rodent species. J. Zool. Lond. 180:367–389.

VAN DER STRAETEN, E. AND D. DIETERLEN. 1987. *Praomys misonnei*, a new species of Muridae from Eastern Zaïre (Mammalia). Stuttgarter Beitr. Naturk. 402:1–11.

VAN DER STRAETEN, E. AND A. M. DUDU. 1990. Systematics and distribution of *Praomys* from Masako Forest Reserve (Zaïre), with the description of a new species. Pp. 73–83 *in* Vertebrates in the tropics, G. Peters and R. Hutterer, eds. Museum Alexander Koening, Bonn, Allemagne.

VERHEYEN, W. N., M. COLYN, AND J. HULSELMANS. 1996. Re-evaluation of the *Lophuromys nudicaudatus* Heller, 1911 species-complex with a description of a new species from Zaire (Muridae—Rodentia). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 66:241–273.

VOGEL, P. 1974. Note sur le comportement arboricole de *Sylvisorex megalura* (Soricidae, Insectivora). Mammalia 38:171–176.

The Birds of Monts Doudou, Southwestern Gabon

Patrice Christy
B.P. 2240, Libreville, Gabon

and

Steven M. Goodman
Field Museum of Natural History,
Roosevelt Road at Lake Shore Drive,
Chicago, Illinois 60605
email: goodman@fmnh.org

Between late February and late March 2000 we conducted an elevational survey of the avifauna occurring on Monts Doudou in extreme southwestern Gabon. Several different techniques were used to census the local birds, including extensive transect surveys during which birds were visually and audibly identified, and also capture of birds using understory mist nets. Mist-netting zones were centered within a range of ± 75 m around the campsites within each elevational zone: camp 1 at 110 m, camp 2 at 350 m, and camp 3 at 625 m.

During our survey of the Monts Doudou massif 230 species of birds were recorded, representing about one-third of the known avifauna of Gabon. In total 173 species were recorded at camp 1 (110 m), 77 species at camp 2 (350 m), 73 species at camp 3 (625 m), and 49 species in the savanna. When these comparisons are restricted to presume resident forest-dwelling species the figures are 151 at camp 1, 77 at camp 2, and 72 at camp 3.

Several species were recorded during the study that were previously unknown from southwestern Gabon. The upper regions of the surveyed massif showed no signs of submontane or montane vegetation. Within the locally occurring ornithological community no trace was found of the mountain harboring "relict" montane forest species providing evidence that the upper slopes of Monts Doudou are a "Pleistocene refuge" for birds.

RÉSUMÉ

Entre la fin du mois de février et la fin du mois de mars 2000, nous avons effectué l'inventaire altitudinal de l'avifaune des monts Doudou dans l'extrême sud-ouest du Gabon. Pour le recensement de l'avifaune, plusieurs techniques ont été utilisées, comprenant l'inventaire sur transects au cours duquel les oiseaux sont identifiés visuellement et auditivement, ainsi que la capture d'oiseaux à l'aide de filets placés dans le sous-bois. Au sein de chaque zone altitudinale: campement 1 à 110 m, campement 2 à 350 m et campement 3 à 625 m, les filets étaient placés sur une zone de ± 75 m autour du campement.

Au cours de cet inventaire, 230 espèces d'oiseaux ont été recensées, représentant à peu près un tiers de l'avifaune connue de Gabon. Au total, 173 espèces ont été répertoriées

autour du campement 1 (110 m), 77 espèces autour du campement 2 (350 m), 73 espèces au campement 3 (625 m) et 49 espèces en savane. Lorsque ces comparaisons sont restreintes aux espèces forestières et présumées résidentes, les chiffres sont: 151 espèces pour le campement 1, 77 espèces pour le campement 2 et 72 espèces pour le campement 3.

Pendant cette étude, nous avons trouvé plusieurs espèces qui étaient auparavant inconnues dans le sud-ouest du Gabon. La région supérieure du massif ne semble montrer aucun signe de végétation montagnarde ou submontagnarde. De la même manière, nous n'avons trouvé aucune espèce d'oiseau de montagne pouvant démontrer l'évidence que la partie supérieure des versants des Monts Doudou est un "refuge pléistocène" pour les oiseaux.

Introduction

Monts Doudou was classified as a protected area of 332,000 ha on 23 January 1998. The principal reasons it was incorporated into Gabon's protected areas system are that the massif and surrounding areas hold a rich flora and the presence amongst the mammals of *Cephalophus ogilbyi crusalbum*, Ogilby's duiker, a subspecies endemic to the country. For a considerable period no information was available on the avifauna of this region. The first preliminary ornithological inventory of the birds of the Moukalaba Reserve, just adjacent to Monts Doudou, was made during a few visits between 1987 and 1992, but only in the southern portion of the reserve and in a zone of mixed savanna and gallery forest. During the course of these visits 278 species of birds were found (Christy, unpublished; Languy, unpublished). To the west of Monts Doudou there is a large assemblage of protected areas (réserves de faune et anciens domaines de chasse) covering 700,000 ha. These protected areas, with a worldwide reputation, are known as the "aire d'exploitation rationnelle de faune de Setté Cama." The establishment of Monts Doudou as a protected area formed a corridor between Setté Cama and Moukalaba (100,000 ha). This series of connected reserves is known as the "complexe d'aires protégées de Gamba" (1,132,000 ha).

The region to the west of Monts Doudou and to the littoral zone, which includes the zones of Gamba and Setté Cama, was the subject of intensive prospection by an ornithologist who was resident at Gamba between 1988 and 1992. These field studies revealed the presence of nearly 400 species (Sargeant 1993). The ornithological richness of this site is related to the large diversity of habitats it contains, including mangroves, coastal lagoons, and *terra firme* forest. The two inventories made in Moukalaba (incomplete) and in the region of Gamba (intensive) comprise the working basis of ornithological information from the southwestern portion of Gabon.

The principal objectives of our ornithological inventory of Monts Doudou were to document the local forest-dwelling species and to examine the altitudinal variation along the slopes of the mountain.

Methods

Three different techniques were used to inventory the birds of Monts Doudou: 1) sight observations and vocal recognition of birds during forest transects, 2) observations along ecotones and very particular habitats, and 3) capture with the use of mist nets. These techniques were used at all three inventoried sites along the slopes of Monts Doudou. Mist-netting zones were centered within a range of ± 75 m around the campsites within each elevational zone: camp 1 at 110 m, camp 2 at 350 m, and camp 3 at 625 m.

Sight observations and auditory recognition

General observations based on visual and vocal recognition can provide information on the birds occurring within a given area. On a massif such as Monts Doudou one can find zones where the avifauna is rich in species and in relatively high density. This technique simply comprises noting all birds observed or heard during the course of a slow promenade. This technique is considered an adaptation in some ways to the more methodologically strict use of point counts. In general our three study sites provided good opportunities for these transects. For example, the presence of the open old logging road close to camp 1 was highly favorable to view canopy birds and to localize by vocalization birds of the understory and intermediate canopy zones. At the upper two sites it was necessary to somewhat adapt this technique, as the trails near camp 2 were largely for timber extraction and in the vicinity of camp 3 were largely those opened by elephants; in both cases these trails were distinctly narrower than near camp 1. At the two upper sites considerable attention was given to vocalizations, and the speed of passing through the transect was distinctly slower than at camp 1, allowing closer observations of birds moving through the forest. An old logging road, about one hour's walk from camp 2 and at 180 m, was used to inventory canopy birds. This road was the continuation of the route passing by camp 1. Given the altitude of this portion of the road, birds observed in this zone were considered as part of the camp 1 transect. In the camp 3 transect, visual and auditory observations were made almost exclusively from elephant trails and largely along a ridge that provided views of more open canopy and the upper portion of the forest.

Given the flat terrain near camp 1 there was no constraint to find sufficient habitat that fell within the elevational transect. However, starting with camp 2, an area of the forest with extensive deep valleys and bisected terrain, the amount of habitat in a lateral sense within the transect zone became much more limited. By camp 3 this problem became even more accentuated and observations were made in a transect ring passing around the summital zone of the mountain.

It is worthwhile to briefly mention the state of the vegetational cover surrounding the study sites. Near camp 1 and camp 2 certain zones within the transects had been selectively logged, and the natural vegetation showed signs of disturbance. However, within these two areas there were considerable areas of forest that showed no sign of selective logging. At camp 3 and across the river where camp 2 was established, the forest showed no signs of disturbance.

Observations in marginal, particular, and ecotonal habitats

In order to make the inventory of the birds of Monts Doudou as complete as possible, visits and observations were made in areas of marginal habitat and zones with very particular habitats within the main forest block. Further, a day was spent observing birds in the ecotonal zone of mixed forest and savanna (on the road towards Doussala, at 8 km from camp 1), as well as in pure savanna.

Within the forest the marginal habitats comprised swamps and marshes bordered by forest vegetation that are the result of the logging road construction that blocked the movement of slow-moving streams. This created a new habitat, which, in turn augmented the bird diversity occurring in the area associated with aquatic and open forest species. In this context several marshes were visited: at about 6.5 km from camp 1 on the road towards Doussala and two marshes between camps 1 and 2 (at 9.5 and 9.7 km from camp 1).

Other marginal habitats included the Gramineae zone along the logging trails. Also, zones with recolonizing or secondary vegetation, associated with disturbance, and largely

composed of Marantaceae and Zingiberaceae. These open habitats explain the presence of normally savanna-dwelling species. The logging roads provide the means for these species to penetrate into the interior of the massif. Further, these zones contain forest-edge bird species.

Also within this group of particular habitats we include forest streams and rivers and associated flooded forest in valley bottoms that can vary greatly in size depending on the extant of rains. Given the topography of the massif this habitat of seasonally inundated forest or swamp forest was well represented at camp 1, which was adjacent to a river. With increasing elevation these swamp forests became rarer and by camp 3 non-existent. The river near camp 2 passed through relatively steep terrain; some portions of the river were with fast-moving water with large water-smoothed rocks and others with waterfalls and quick drop-offs. The lower portions of this river were censused for birds living in the smaller forested streams.

One specific habitat that we were hoping to find towards the summital zone of the mountain, but to no avail, was submontane forest. This habitat is known in Gabon by several small parcels on the highest summits above 900 m of Monts de Cristal (northwest), Chaillu Massif (center), and the Bélinga complex (northeast). The summital zone of the mountain we surveyed in the Monts Doudou complex was 660 m, which explains the absence of submontane forest. To the north of the site we inventoried and within the Monts Doudou complex there is a massif, Mt. Igoumbi, that reaches 820 m and the vegetation and avifauna of the summital area perhaps has submontane components.

Ornithological censuses were also conducted in the forest-savanna ecotone and savanna habitat. Information from these zones augmented data on the different bird species occurring in the reserve. Further, knowledge of the birds found in these habitats provided insight into the distributions of forest birds that occur to the savanna edge and savanna birds that are found just to the forest edge. There is also a limited group of bird species that typically occur at the forest edge, that is to say they are never found deep within the main forest block or in open savanna.

Mist-netting

We used this technique to provide measures of relative abundance of understory birds as measured by the number of captures per mist-net day. Further, mist nets were employed to supplement information obtained from different observation techniques on the presence of different bird species within each elevational zone. All nets were 35 mm mesh size, 2.6 m high, and 12 m long. The bottom rung of the nets were either touching or within 10 cm of the ground.

Many captured birds were weighed, measured, and marked before being released near the original site of capture. A mark was made on the bird's primary feathers with indelible ink. Within each elevational zone the first primary was marked for birds captured on the first day of netting, the second primary on the second day, and so on until the fifth and final day of netting. This marking technique provided a means to recognize recaptured individuals and the chronology of the recaptures. Some birds were collected and prepared as either standard study skins, skeletons, or fluid preserved specimens. Tissue samples of collected individuals were preserved in a solution of EDTA. The specimens are deposited in the Field Museum of Natural History, Chicago.

RESULTS

This first ornithological survey of Monts Doudou recorded 230 species of birds—the total known avifauna of Gabon is 680 species (Christy, unpublished data). In Table 1 we present a list of the bird species found in the reserve along with information on their status (precisely, those that are Palearctic or Afrotropical migrants), their habitat, and their elevational distribution amongst the three sites studied. In total 173 species were recorded at camp 1 (110 m), 77 species at camp 2 (350 m), 73 species at camp 3 (625 m), and 49 species in the savanna. When these figures are restricted to presume resident forest-dwelling species the figures are 151 at camp 1, 77 at camp 2, and 72 at camp 3.

Of the 230 species recorded during this inventory, 216 are local breeding residents, and the balance of the 14 remaining species are migratory — 9 from regions of the Afrotropics and 5 from the Palearctic. A breakdown of the 216 resident species shows that 161 species (74%) are forest-dwelling, 43 species (19%) are restricted to the savanna, and 12 species (5.5%) are forest-edge species. Birds falling into this latter group were not found within the main forest or they were only found on the edge of the logging road.

An analysis of the elevational range of the 161 species of forest birds shows that 52 were observed at all three sites, 35 at two of the three sites, and 74 were restricted to a single site. Of the 74 species restricted to a single site, 66 species were observed at site 1. One explanation for the relatively elevated figure of site 1 restricted species is, for example, the area within the camp 1 transect zone was the subject of much more extensive exploration and variable habitats. As a result of 23 km of logging roads within this zone, it was much easier to census canopy species. Also within this zone were several species of forest-edge species (11 of 12) and a few savanna species such as the pipit *Anthus pallidiventris*. Even after the removal of all of these strictly non-forest species, species richness was higher at the first site than the upper two. By contrast, the number of bird species documented at the upper two zones was similar.

With increasing altitude and topographical relief, the second and third sites showed much more vegetational homogeneity, and, more importantly, limited working areas along a horizontal axis falling within each respective elevational transect zone. We suspect that within the altitudinal breadth of our transect, from 110 to 625 m, a substantial portion of the forest avifauna occur across the complete gradient, but with increasing elevation there is a reduction in population density rather than a distinct reduction in species richness.

At the second site we found two species that were not found at the other two sites. One of these, *Motacilla clara*, can easily be explained by the presence of a riparian habitat not found in the other two zones — a river with relatively fast-moving water with large rocks and areas with sandy banks. The presence of the second species, *Criniger ndussumensis*, cannot be explained by any particular local forest habitat. This is a species that presumably occurs across the complete elevational transect and was simply missed at the other sites.

It is particularly interesting to note that the third site held two birds that were not found at any other site: *Picathartes oreas* and *Hirundo fuliginosa*. In both cases these species use large exposed blocks of rock for nesting sites, and such habitat was largely confined to the upper reaches of the massif.

Another four species were only observed at the third site, and for two of these birds, *Campethera nivosa* and particularly *Nigrita canicapilla*, there is no clear ecological explanation for their restricted distributions. The *Nigrita* was not vocalizing during the period of our inventory, which might explain why it was missed at the lower two sites. The other two species, *Parus funereus* and *Sheppardia cyornithopsis,* are forest-dwelling birds that are

TABLE 1. List of species found on Monts Doudou during the 2000 survey. For a few species scientific names are presented just to the level of subspecies to indicate that there is a difference of opinion amongst taxonomists concerning the specific status of the taxon.

Status only indicated for Afrotropical migrants (=AM) and Palearctic migrants (=PM) and for those species occurring at the forest edge (=FE) and savanna (=S). The absence of any code in this column signals that the species is a forest-dwelling bird and is presumably sedentary and a local breeding resident.

Species	Status	Camp 1 110 m	Camp 2 350 m	Camp 3 625 m	Savanna
Ixobrychus sturmii	AM	X			
Scopus umbretta		X			
Ciconia episcopus	S	X			
Bostrychia hagedash		X			
Bostrychia olivacea		X		X	
Bostrychia rara		X	X	X	
Pteronetta hartlaubii		X			
Aviceda cuculoides		X			
Pernis apivorus	PM	X			
Gypohierax angolensis		X			
Polyboroides typus		X			
Accipiter erythropus		X			
Urotriorchis macrourus		X			
Buteo auguralis	AM	X			
Spizaetus africanus		X			
Stephanoaetus coronatus		X	X	X	
Francolinus lathami		X			
Francolinus squamatus	FE	X			
Francolinus afer	S				X
Agelastes niger		X			
Guttera plumifera		X			
Himantornis haematopus		X			
Sarothrura pulchra		X			
Canirallus oculeus		X			
Crecopsis egregia	AM				X
Podica senegalensis		X	X		
Actophilornis africanus	AM	X			
Columba unicincta		X	X	X	
Columba delegorguei iriditorques		X			
Streptopelia semitorquata	FE	X			X
Turtur afer	S				X
Turtur tympanistria		X	X		
Turtur brehmeri		X	X	X	
Treron australis		X	X	X	
Psittacus erithacus		X	X	X	
Poicephalus gulielmi		X	X	X	
Agapornis pullarius	S				X
Tauraco persa	FE	X			
Tauraco macrorhynchus		X	X	X	
Corythaeola cristata		X	X	X	
Cuculus solitarius		X			
Cuculus clamosus		X			
Chrysococcyx cupreus		X			
Chrysococcyx flavigularis		X			
Ceuthmochares aereus		X	X	X	

	Status	Camp 1	Camp 2	Camp 3	Savanna
Centropus anselli		X			
Centropus senegalensis	S				X
Glaucidium sjostedti		X	X	X	
Strix woodfordii		X		X	
Caprimulgus pectoralis	S				X
Caprimulgus batesi		X			
Telacanthura melanopygia		X			
Rhaphidura sabini		X			
Neafrapus cassini		X	X		
Apus aequatorialis	AM				X
Apus apus	PM	X		X	
Apus batesi		X			
Colius striatus	S				X
Apaloderma narina		X	X	X	
Apaloderma aequatoriale		X		X	
Alcedo quadribrachys		X			
Alcedo leucogaster		X	X		
Halcyon badia		X	X	X	
Halcyon malimbica		X	X		
Halcyon senegalensis	AM	X			
Megaceryle maxima		X			
Merops breweri	FE	X			
Merops muelleri		X			
Merops gularis		X			
Merops pusillus	S				X
Merops variegatus	S				X
Merops bullockoides	S				X
Merops albicollis	AM				X
Merops malimbicus	AM	X			
Eurystomus glaucurus	AM	X			X
Eurystomus gularis		X			
Tropicranus albocristatus		X		X	
Tockus hartlaubi		X			
Tockus camurus		X	X	X	
Tockus fasciatus		X	X	X	
Bycanistes fistulator		X		X	
Bycanistes cylindricus albotibialis		X			
Ceratogymna atrata		X	X	X	
Gymnobucco calvus		X			
Gymnobucco peli		X			
Gymnobucco bonapartei	FE	X			
Buccanodon duchaillui		X	X	X	
Pogoniulus scolopaceus		X	X	X	
Pogoniulus bilineatus	S				X
Pogoniulus subsulphureus		X	X	X	
Pogoniulus atroflavus		X	X	X	
Tricholaema hirsuta		X	X	X	
Trachyphonus purpuratus		X			
Prodotiscus insignis		X			
Indicator maculatus		X			
Campethera cailliautii permista		X		X	
Campethera nivosa				X	
Campethera caroli		X	X		
Dendropicos gabonensis		X			

135

	Status	Camp 1	Camp 2	Camp 3	Savanna
Smithornis rufolateralis		X	X		
Pitta angolensis		X			
Psalidoprocne nitens		X	X		
Psalidoprocne pristoptera petiti	S				X
Hirundo semirufa	S				X
Hirundo abyssinica	S				X
Hirundo fuliginosa				X	
Hirundo rufigula	S				X
Hirundo nigrita		X			
Hirundo rustica	PM				X
Delichon urbica	PM	X			
Motacilla clara			X		
Anthus pallidiventris	S	X			
Coracina azurea		X	X		
Andropadus virens		X	X	X	
Andropadus gracilis		X	X		
Andropadus ansorgei		X			
Andropadus curvirostris		X			
Andropadus gracilirostris		X	X	X	
Andropadus latirostris		X	X	X	
Calyptocichla serina		X	X	X	
Baeopogon indicator		X		X	
Baeopogon clamans		X	X		
Ixonotus guttatus		X	X		
Chlorocichla simplex	S				X
Chlorocichla flavicollis	S				X
Thescelocichla leucopleura		X			
Phyllastrephus icterinus		X	X	X	
Phyllastrephus xavieri			X	X	
Phyllastrephus albigularis		X	X	X	
Bleda syndactyla		X	X	X	
Bleda notata		X	X		
Criniger chloronotus		X	X	X	
Criniger calurus		X	X		
Criniger olivaceus ndussumensis			X		
Pycnonotus barbatus	S				X
Neocossyphus rufus		X	X	X	
Neocossyphus poensis		X	X		
Stizorhina fraseri		X	X	X	
Alethe diademata castanea		X	X	X	
Alethe poliocephala		X	X	X	
Stiphrornis erythrothorax		X	X	X	
Sheppardia cyornithopsis				X	
Erythropygia leucophrys	S				X
Myrmecocichla nigra	S				X
Sylvietta virens		X			
Sylvietta denti		X			
Macrosphenus concolor		X	X	X	
Macrosphenus flavicans		X		X	
Hylia prasina		X	X		
Sylvia borin	PM				X
Cisticola natalensis	S				X
Cisticola brachypterus	S				X
Cisticola lateralis	S				X

	Status	Camp 1	Camp 2	Camp 3	Savanna
Cisticola bulliens	S				X
Cisticola erythrops	S				X
Prinia subflava	S				X
Prinia bairdii		X			
Apalis rufogularis		X	X	X	
Camaroptera brachyura	S				X
Camaroptera superciliaris		X			
Camaroptera chloronota		X			
Fraseria ocreata		X	X	X	
Muscicapa olivascens			X	X	
Muscicapa infuscata		X		X	
Myioparus griseigularis		X		X	
Dyaphorophyia concreta		X	X	X	
Dyaphorophyia castanea		X	X	X	
Dyaphorophyia tonsa		X	X	X	
Platysteira cyanea	S				X
Erythrocercus mccallii		X			
Elminia nigromitrata		X			
Trochocercus nitens		X	X		
Terpsiphone rufiventer		X	X		
Illadopsis fulvescens		X	X	X	
Illadopsis rufipennis		X		X	
Illadopsis cleaveri		X	X	X	
Picathartes oreas				X	
Parus funereus				X	
Anthreptes fraseri		X	X	X	
Anthreptes rectirostris		X	X	X	
Anthreptes collaris		X	X	X	
Nectarinia seimundi		X		X	
Nectarinia batesi		X			
Nectarinia olivacea		X	X	X	
Nectarinia cyanolaema		X	X	X	
Nectarinia rubescens		X			
Nectarinia chloropygia	FE	X			
Nectarinia minulla		X			
Nectarinia johannae		X			
Nectarinia superba		X			
Oriolus brachyrhynchus		X	X	X	
Oriolus nigripennis	FE	X			
Dryoscopus senegalensis	FE	X			
Dryoscopus sabini		X	X		
Tchagra australis	FE				X
Tchagra senegala	S				X
Laniarius bicolor	S				X
Laniarius leucorhynchus	FE	X			
Malaconotus cruentus		X			
Nicator chloris		X	X	X	
Prionops caniceps		X	X	X	
Dicrurus atripennis		X	X		
Dicrurus adsimilis		X			
Onychognathus fulgidus		X	X		
Lamprotornis purpureiceps		X	X	X	
Lamprotornis splendidus	FE	X			
Buphagus africanus	S				X

137

	Status	Camp 1	Camp 2	Camp 3	Savanna
Ploceus nigerrimus	S				X
Ploceus cucullatus	S				X
Ploceus tricolor		X			
Ploceus superciliosus	S				X
Malimbus nitens		X			
Malimbus cassini		X			
Malimbus rubricollis		X			
Malimbus erythrogaster		X			
Euplectes hordeaceus	S				X
Euplectes macrourus	S				X
Euplectes ardens	S				X
Parmoptila woodhousei		X	X	X	
Nigrita canicapilla				X	
Nigrita luteifrons		X			
Nigrita bicolor		X			
Nigrita fusconota		X			
Pyrenestes ostrinus	FE	X			
Spermophaga haematina		X			
Clytospiza monteiri	S				X
Estrilda melpoda	S				X
Lonchura cucullata	S				X
Vidua macroura	S				X
Serinus mozambicus	S				X
Total species		173	77	73	49
Total forest-restricted presumed breeding species	161	151	77	72	

relatively poorly known and that were first detected by song. *Sheppardia* occurs in zones with dense vegetation around dead and fallen trees and often near water, where it forages on or close to the ground. This type of habitat is distinctly more common on steep forested slopes than in flat lowland areas. On the other hand, this species is also known to occur in a completely different type of habitat—the ecotone between swamp forest and upland forest. This habitat type was common in the area surrounding camp 1.

After the inventory of Monts Doudou, a list of known Gabonese, forest-dwelling, bird species that could possibly be found at this site was drawn up. This list comprises 72 supplementary species of which 42 were previously known from the Gamba area or the gallery forest of the Moukalaba Reserve. One of these species of particular interest is *Anas sparsa*, which appears to be limited in Gabon to rivers passing through forest. This duck was not found during our inventory of the Monts Doudou massif, which seems to contain ideal habitat for this bird and we strongly suspect that it was simply missed. The closest known site to Monts Doudou for this species is Mt. Tandou to the north, where H. Beatty collected a pair in June 1951 (Rand et al. 1959).

A few groups were poorly represented during our inventory, most notable in this regard were forest-dwelling *Accipiter* spp. (one was captured in a mist net but escaped before it could be removed and identified), nocturnal raptors (the small number of species observed is surprising given that we were in the forest over thirty nights and often the first hours after night fall were spent listening for calling birds), honeyguides (they were not calling during the period of this inventory), forest flycatchers, and forest weavers.

TABLE 2. Mass data from netted birds based on adults, unless otherwise stated.

Species	Mass (g)
Glaucidium sjostedti	155
Alcedo quadribrachys	33.5
Alcedo leucogaster	15.0
Halcyon badia	58
Magaceryle maxima	315
Tricholaema hirsuta	52
Indicator maculatus	46.0
Campethera nivosa	25.0, 34.5
Campethera caroli	63
Pitta angolensis	73
Motacilla clara	22.5
Andropadus virens	22.5 (fledgling)
Andropadus latirostris	26.0 (immature), 31.5, 32.0
Phyllastrephus icterinus	19.6 ± 1.46 (17.0–21.5, n = 3)
Phyllastrephus xavieri	23.3 ± 0.62 (22.5–24.0, n = 3)
Phyllastrephus albigularis	21.5, 27.0
Bleda syndactyla	43.0, 48.5
Bleda notata	31.5, 35.0
Criniger chloronotus	46.0 ± 1.47 (44.0–47.5, n = 3)
Criniger calurus	23.5, 29.0
Neocossyphus rufus	58.0 ± 2.16 (56–61, n = 3)
Neocossyphus poensis	49.0
Alethe diademata castanea	32.0 ± 0.82 (31.0–33.0, n = 3)
Alethe poliocephala	39.5, 45.0
Stiphrornis erythrothorax	18.5 ± 1.43 (16.5–20.5, n = 3)
Camaroptera chloronota	8.3
Myioparus griseigularis	12.0
Dyaphorophyta concreta	11.0, 13.5
Terpsiphone rufiventer	16.0
Illadopsis rufipennis	26.0
Illadopsis cleaveri	29.5
Anthreptes fraseri	13.5
Nectarinia olivacea	11.5 ± 0.71 (11.0–12.5, n = 3)
Nicator chloris	44.0
Parmoptila woodhousei	10.0

Relatively few birds were captured by use of mist nets. Given that few data are available on the masses of birds in this portion of Africa we present this information for birds captured by mist nest (Table 2).

DISCUSSION

The inventory of the birds of Monts Doudou has two principal interests:

1. To fill in a major gap in information on the forest-dwelling birds in the southwestern portion of the country. Today, this region is separated from the large forest block in central and northern Gabon by two savanna corridors which follow the Ngounié and Nyanga valleys, and much further to the north the Ogooué Basin. Monts Doudou represent the northern extension of the Mayombe Massif in the Congo. On the basis of paleoclimatological

data this zone was completely isolated from the large forested zones of central and northern Gabon approximately 2500 years ago, a dry period across central Africa (Maley 1997).

2. To test the hypothesis that for birds the upper slopes of Monts Doudou might represent a forest "Pleistocene-refuge" for species that were much more widely distributed several thousand years ago, before the above stated dry period.

A few species of birds occurring in montane or submontane forest types have been found in the Congo extension of the Chaillu Massif at a elevation of 500–600 m, most notably *Zoothera crossleyi* and *Dryoscopus angolensis* (Dowsett-Lemaire and Dowsett 1991). These two species, which are apparently good indicators of former connections between forest blocks during wetter geological periods, are unknown from Gabon, but have been recorded further to the north in Cameroon. Given the geographical position and elevational range of Monts Doudou these two species were searched for during our inventory. However, in this regard, it is important to reiterate that the maximum elevational range of our survey was 660 m, rather close to the known lower limit of these species and generally outside of the elevational range of other bird species with montane affinities. Inventories of higher zones within the Monts Doudou complex, most notably Mt. Igoumbi (820 m), need to be conducted to definitively establish if these species are absent from the mountain chain. Further, the bird faunas of the summital zones of the highest mountains in Gabon (all above 1000 m), particularly Mt. de Cristal in the northwest, Mt. Bélinga in the northeast, and the Chaillu Massif in the central south, are largely unknown and may contain traces of these "Pleistocene-refuge" species.

From a biogeographic perspective, the occurrence of *Picathartes oreas* on Monts Doudou is probably one of the more important ornithological findings of this survey. This site represents the southernmost limit of this species, which also occurs in the forested zones of Cameroon, Equatorial Guinea, and northern and central Gabon. This bird lives in a very particular forested habitat — sites with large exposed blocks of rock or caves, which are used as nesting and resting sites. The population of this species found in Monts Doudou is presumably isolated from other populations occurring in Gabon. This species probably does not disperse widely and is rather sedentary. Finally, this species is not known from the Mayombe region of the Congo.

Observations of reproduction

In Gabon the breeding season of most forest birds is principally during the two rainy seasons (from February to May, and from September to December) and the intermediate short dry season in January. During the course of our work on Monts Doudou several casual observations were made associated with the reproduction of a few species.

Camp 1 transect (110 m)

25 February: young *Anthreptes rectirostris* being fed by an adult, *Anthreptes collaris* with young, and *Bleda notata* captured with a vascularized brood patch.

26 February: *Neafrapus cassini* with a twig in its bill, two different *Bleda syndactyla* captured with vascularized brood patches, and a collected *Bleda notata* had slightly enlarged ovarian follicles.

28 February: young *Camaroptera chloronota* captured in mist nets.

1 March: juvenile *Stiphrornis erythrothorax* captured in mist nets; young *Dicrurus atripennis* begging for food.

2 March: *Dyaphorophyia castanea* with young; *Calyptocichla serina* feeding young at nest.

3 March: young *Oriolus brachyrhynchus*.
7 March: construction of nest by *Sylvietta denti*.

Camp 2 transect (350 m)
10 March: fledgling *Andropadus virens* captured in mist net.

Camp 3 transect (625 m)
16 March: pair of *Tropicranus albocristatus* with begging young, a captured *Tricholaema hirsuta* with vascularized brood patch, and a captured *Neocossyphus rufus* with vascularized brood patch.
17 March: young *Myioparus griseigularis* captured in mist nets.
18 March: young *Andropadus latirostris* and *Alethe poliocephala* with highly vascularized brood patch obtained in mist nets, and collected *Neocossyphus rufus* and *Alethe diademata castanea* with enlarged testes.
19 March: juvenile *Glaucidium sjostedti* with an adult.

SPECIES ACCOUNTS

Several species found on the slopes of Monts Doudou are poorly known from the ornithological literature in the context of their natural history and their distribution, or are considered rare. In this section we present information on such birds.

Bostrychia olivacea
This forest ibis is very poorly known and is difficult to observe during the day when it forages on the ground. The best circumstances for finding this species are at dawn or at dusk when it is flying from or to its sleeping roost. When flying it typically utters very distinctive contact calls, which can be heard from a considerable distance. At camp 1 this ibis called nearly every evening, between 1830 and 1900 hours, and in a few cases stopped for a moment in the large trees in the swamp forest near the camp. More interesting was that this species was heard calling at camp 3 in the early morning starting at about 6 hours, as it passed over different valleys. In the southwestern portion of Gabon it is known from the region of Setté Cama since the 19th century, and is regularly found in swamp forest and at the edge of lagoons. It is also known from the forests southeast of Gamba. Another forest ibis, *Bostrychia rara*, which has a wider distribution, was found at all three of the sites surveyed on Monts Doudou.

Canirallus oculeus
This forest rail is very poorly known and difficult to observe. It is widely distributed across Gabon from the coast to the extreme north of the country, but seems to be confined to swamp forest. Its extraordinary vocalizations allow for simple verification of its local presence. A pair was found on two consecutive nights in the swamp forest not far from camp 1.

Chrysococcyx flavigularis
This small cuckoo, the least common of the four *Chrysococcyx* occurring in Gabon, can be easily localized by its call. The record of *C. flavigularis* from Monts Doudou appears to be the first record of it in southwestern Gabon. It is also known from the Mayombe region of the Congo (Dowsett-Lemaire and Dowsett 1991).

Glaucidium sjostedti

This small forest owl is broadly distributed across Gabon, but remains poorly known. It seemed to be relatively common on Monts Doudou, as it was seen or heard nearly every evening across the complete elevational range of our survey. It was observed during the day on 19 and 20 March near camp 3. Here a pair was found in a small valley in the company of at least one juvenile that had recently fledged and remained close to one of the adults. One adult captured large insects until 915 hours, but was regularly heard calling and viewed in the company of the juvenile until 1500 hours. This partial diurnal behavior is presumably related to providing food for the juvenile. During the morning this species regularly gave a song or perhaps contact call, which is poorly known and very different than its nocturnal vocalizations. Individuals of *Nectarinia olivacea* and *Dyaphorophyia tonsa* were observed harassing one of the adult owls.

Telacanthura melanopygia

This poorly known and seemingly rare, large, forest swift was observed several times hawking insects above the logging road near camp 1. This species has been previously noted in the region of Gamba.

Apus batesi

This small swift was previously observed in the Moukalaba Reserve. In general it is difficult to observe flying above the tree canopy, which may be the reason there are so few reports from Gabon. During the survey of Monts Doudou it was noted flying above the logging road not far from camp 1. It is believed that this species nests in the abandoned or usurped nests of the swallow *Hirundo fuliginosa*, but more recent observations indicate it appropriates the nests of savanna swallows, which may provide the means for this swift to extend its geographical range.

Caprimulgus pectoralis

This nightjar was heard calling at twilight near the village of Doussala. This is the first record of this species in the southwest of Gabon. The nearest known locality is in the southeast along the Batéké Plateau.

Merops muelleri

This forest species is widespread in Gabon, particularly on the interior plateau and massifs of relatively high elevation. Given that this bee-eater is largely a canopy species, it is diffuclt to observe inside of the forest. Pairs of this species were observed along the logging road below camp 2. It was previously unknown in southwest Gabon, but has been reported from the Mayombe region of Congo (Dowsett-Lemaire and Dowsett 1991).

Tricholaema hirsuta

This species is distributed throughout much of Gabon. Of most interest is the subspecific identification of one individual captured at Monts Doudou by the use of mist nets. Two subspecies, clearly differentiated, occur in Gabon. *Tricholaema h. flavipunctata* is found throughout much of the country, but is replaced in the southwest by *T. h. angolensis*. Material collected in the southwest by Beatty, and most notably at Lébamba, was referable to the form *T. h. angolensis* (Rand et al. 1959). Nevertheless, birds obtained by Beatty at Mt. Tandou, north of Monts Doudou, are referable to *T. h. flavipunctata*, as are specimens from Mt. Chaillu. Rand et al. (1959) analyzed the distribution of these two sub-

species in Gabon and concluded that they abruptly replace one another with no sign of integradation in the zone of contact. The line separating these two forms is situated in southern Gabon near the 2° parallel south. The individual obtained at Monts Doudou, which is referable to *T. h. angolensis*, confirms this.

Pitta angolensis

This pitta is one of the more difficult African forest species to observe, even though it has brilliant coloration. The utilization of mist nets placed in the understory, is one of the better techniques to document the presence of pittas. Also, knowledge of their calls provides another means to census these birds. These two methods revealed the presence of this species within the camp 1 transect zone. It was netted in swamp forest. Further, this species was observed along a slope in terra firma forest in a zone with a dense understory, entanglements of vegetation, and fallen and rotten tree trunks. The call of this species is actually a mechanical noise made with the wing feathers. The call, associated with territory defense, was heard during the morning and afternoon, sometimes for long periods, between 26 February to 3 March. On the basis of the configuration of sites this species was heard calling from, it appeared that two territorial males were involved. It is presumed that *P. angolensis* breeds in the vicinity of our camp 1 zone. Information on this species in Gabon is rare, but there is a record from Moabi, about 50 km direct line from camp 1 (Malbrant and Maclatchy 1949). These observations confirm the local occurrence of this species in the southwest, and that *P. angolensis* is the form occurring in the central and eastern portions of the country. *Pitta reichenowi*, considered by some authorities to be a subspecies of *P. angolensis*, occurs in the northern portion of the country.

Hirundo fuliginosa

The occurrence of this forest-dwelling swallow at Monts Doudou extends its known range in Gabon to the southwest. This species' distribution seems to be limited by the availability of nest sites. Its mud-constructed nests are attached to the sides of large blocks of rock. This explains why this species is more common in the interior plateaus of Gabon and on the taller mountains than in the coastal basins. The closest known sites to Monts Doudou for this species are the Mouila region and the Chaillu Massif.

Sheppardia cyornithopsis

Little is known about this small forest turdid. The occurrence of this species on Monts Doudou represents an extension of its geographical range into southwestern Gabon. In the northeast of the country it is relatively common in tall marsh forest or the ecotone between swamp forest and terra firma forest. In the central portion of Gabon, it was found in terra firma forest with dense understory. On Monts Doudou this species was only located in the camp 3 zone in an area near a slightly swampy valley with numerous rotten and fallen trees and a dense understory with several recolonizing plant species filling in a tree-fall hole. This species should also occur in the swamp forests near camp 1.

Phyllastrephus albigularis

This understory bulbul was found at all three surveyed forest sites on Monts Doudou. These records appear to be the first of it in this area of southwestern Gabon, where this species seems relatively common. It is also known from the Mayombe region of the Congo.

Phyllastrephus xavieri

Phyllastrephus xavieri is very similar in appearance to *P. icterinus*, and is distinguished from the former by its vocalizations and its external morphology—its head is distinctly flatter and its bill longer. In western Gabon *P. xavieri* is not known from the low-lying coastal forests. Its occurrence on Monts Doudou significantly extends its range into southwestern Gabon.

LITERATURE CITED

DOWSETT-LEMAIRE, F. AND R. J. DOWSETT. 1991. The avifauna of the Kouilou basin in Congo. Tauraco Research Report n° 4.

MALBRANT, R. AND A. MACLATCHY. 1949. Faune de l'Equateur africain français, I Oiseaux. Lechevalier, Paris.

MALEY. 1997. Middle to late Holocene changes in tropical Africa and other continents. Paleomonsoon and sea surface temperature in third millenium BC climate change and old world collapse. Pp. 611–640 *in* NATO Adv. Sc. Inst. Series, Global Environmental Change, H. N. Dalfes, G. Kuklar, and H. Weiss, eds. Springer, Berlin.

RAND, A. L., H. FRIEDMANN, AND M. A. TRAYLOR, JR. 1959. Birds from Gabon and Moyen Congo. Fieldiana: Zoology 41:219–413.

SARGEANT, D. 1993. A birders guide to Gabon, West Africa. privately published.

Amphibians and Reptiles of Monts Doudou, Gabon: Species Turnover Along an Elevational Gradient

Marius Burger
Life Sciences Division, South African Museum, P.O. Box 61,
Cape Town 8000, South Africa.
Also at Avian Demography Unit, University of Cape Town,
Rondebosch 7701, South Africa; email: sungazer@iafrica.com

William R. Branch
Department of Herpetology, Port Elizabeth Museum, P.O. Box 13147,
Humewood 6013, South Africa; email: pemwrb@zoo.upe.ac.za

and

Alan Channing
Department of Zoology, University of the Western Cape, Private Bag X17,
Bellville 7535, South Africa; email: achanning@uwc.ac.za

A 28-day-long herpetofaunal survey was conducted in the Monts Doudou-Moukalaba reserve complex in southwestern Gabon during February/March 2000. Methods included 22 days (or 726 trap-days) using pitfall traps in combination with drift fences set at three elevational zones. The main objectives were to determine the species richness of this region and to study partitioning of the various species along an elevational gradient, i.e., between 100 and 660 m.

A total of 78 species comprising 54 amphibians and 24 reptiles were recorded during this survey, and another eight reptile species were recorded subsequently. The real reptile richness of Monts Doudou is believed to be much higher than the current total of 32 species. In contrast, the 54 amphibian species constitutes a relatively high richness for a single locality, especially considering that 72 species are known from the whole of Gabon (Blanc and Frétey 2000b; Frétey and Blanc 2000). Six of the Monts Doudou amphibian species, including the genera *Hemisus* and *Kassina*, were new for Gabon.

Comparisons of amphibian species turnover along the elevational gradient revealed only moderate evidence of altitudinal effects. Increased surveying efforts in this region would most likely disprove some of the current recorded species composition differences. A subset of our results showed greater variation between sites at the same elevation, thus suggesting that the effects of ecotones in a heterogeneous forest habitat may be more influential as a determinant of amphibian communities.

Alpha-level taxonomy of African amphibians and reptiles is generally still rudimentary and most of the central African countries have been neglected in this regard. It is imperative that countries like Gabon develop local expertise to address these herpetological shortfalls.

RÉSUMÉ

Un inventaire herpétofaunal de 28 jours a été conduit au complexe de réserve de Mont Doudou-Moukalaba au Sud-Ouest du Gabon, pendant février-mars 2000. Les trous-pièges combinés avec les haies de conduite en plastique ont été laissées sur trois zones d'élévation pendant 22 jours, soit pendant un total de 726 nuits-pièges. Les objectifs principaux de l'étude étaient de déterminer la richesse spécifique de l'herpétofaune de cette région et de voir la répartition de ces espèces le long du gradient d'élévation entre 100 et 660m.

Un total de 78 espèces comprenant 54 amphibiens et 24 reptiles ont été recueillies pendant l'inventaire et 8 autres espèces de reptiles ont été trouvées ultérieurement. La richesse réelle en reptiles de la région est considérée plus élevée que l'actuel total de 32 espèces. Cependant, la richesse de 54 espèces d'amphibiens est relativement élevée pour une seule localité si on considère qu'un total de 72 espèces sont connues dans tout le Gabon (Blanc et Frétey 2000b, Frétey et Blanc 2000). Six des espèces d'amphibiens récoltées au Mont Doudou, y compris les genres *Hemisus* et *Kassina*, sont nouvelles pour le Gabon.

Les comparaisons des successions d'espèces d'amphibiens le long du gradient d'élévation révèlent une évidence modérée des effets de l'altitude. L'accroissement d'effort de capture dans cette région refutera les quelques différences enregistrées quant à la composition en espèces pour chaque élévation.

Une partie de nos résultats a montré une variation plus élevée entre les sites de même élévation, suggérant ainsi que les effets des écotones dans les forêts hétérogènes pouvaient être plus influents pour la détermination des communautés d'amphibiens. L'alpha-taxonomie des reptiles et amphibiens africains est encore généralement rudimentaire et beaucoup de pays africains ont été négligés de ce point de vue. Il est impératif que ces pays, tels que le Gabon, développent une expertise locale pour surmonter ces retards herpétologiques.

One of the clear things about the African amphibian fauna is that we still know very little about it.

– Poynton (1996)

INTRODUCTION

Herpetofaunal surveys of central African countries have generally been conducted in a nonsystematic fashion with some countries being very well studied and others almost completely ignored to date. The recent syntheses by Frétey and Blanc (2000) presented amphibian species checklists for Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, the Democratic Republic of Congo (DRC), and the oceanic islands off Gabon and Equatorial Guinea. The total of 72 species for Gabon is not very high when compared with neighboring countries such as the DRC (216) and Cameroon (194). The relatively low amphibian species richness in Gabon may be related to its smaller size (i.e., 268,031 km^2 versus DRC 2,344,113 km^2 and Cameroon 475,500 km^2) and less diversity of habitat and altitude, but it may also be a result of insufficient field surveys conducted here. The reptile fauna of Gabon has never been subjected to a comprehensive regional synthesis and species richness figures are thus not readily available. However, the situation is likely to be similar to the amphibian fauna, i.e., under represented due to a paucity of inventorial studies.

The first notable reports on amphibians and reptiles from this region were compiled by Duméril (1856), Hallowell (1857), Günther (1896), Boulenger (1899, 1900) and Mocquard (1897a, b; 1902). Louis-Philippe Knoepffler's herpetological works in Gabon were varied and included some localized and regional faunal assessments (Knoepffler 1966a, 1967a, 1968, 1974, 1979), taxonomy (Knoepffler 1967b, 1967c), ecology (Knoepffler 1965, 1966b, 1967d, 1976) and parasitology (Euzet et al. 1966, Combes and Knoepffler 1967, Maeder et al. 1969, Dupouy and Knoepffler 1978). Recent publications dealing with herpetofaunal surveys in Gabon are by Toft (1982), Waardenburg and Guicherit (1991), Blanc (1998), Frétey and Blanc (2001), Frétey and Dewynter (1998), Blanc and Frétey (2000a), Lötters et al. (2000), Lötters et al. (2001), Gossman et al. (2002) and Pauwels et al. (2002a, b). Some recent taxonomic treatments and species descriptions which include Gabon fauna are by Ohler and Kazadi (1990), Ohler (1996, 1999), Amiet (2000), Bour (2000), and Bauer and Pauwels (2002). Gramentz (1998a, 1998b, 1999a, 1999b, 1999c, 2001) has published on the morphological variation, ecology, and conservation of various Gabon reptile species. Important marine turtle breeding sites along the Gabon coast have been recognized, e.g., Fretey (1998) and Billes (2000).

This paper reports on the herpetological results of a multi-disciplinary biological inventory that was conducted in the Monts Doudou-Moukalaba reserve complex in southwestern Gabon during February/March 2000. The main objectives were to determine the species richness of this region and to study partitioning of the various species along an elevational gradient, i.e., between 100 and 660 meters above sea level. As far as we are aware, no herpetological studies had previously been reported for this region.

DESCRIPTION OF STUDY AREA

The Monts Doudou-Moukalaba reserve complex is part of a series of eight protected areas in the Gamba region, Province Ogoué-Maritime, southwestern Gabon. These protected areas are situated in the biologically diverse Atlantic Equatorial Forest ecoregion, which represents a transition between the tropical forest zones and the savanna ecosystems of the south. More specific details on the region's geographical location, climate, geomorphology and geology, soils, hydrology and meteorology are presented by Thibault et al. (this volume).

The main focus of our fieldwork was at three camps along an elevational gradient. These were Camp 1 (site 6) at 110 m, Camp 2 (site 8) at 350–425 m and Camp 3 (site 9) at 585–660 m. Fieldwork was also conducted at a few nearby localities. Geographical and habitat details of the ten study sites follow:

1. Doussala village and immediate surroundings. Habitat is open savanna with small marshes: Reserve de Faune de la Moukalaba-Dougoua, 02°20.16'S, 10°35.47'E, alt. 100 m. Survey effort at this locality was opportunistic searching during one afternoon and one night.

2. Forest habitat with a small stream: Reserve de Faune de la Moukalaba-Dougoua, 10.8 km 214° SW of Doussala, 02°25.36'S, 10°32.72'E, alt. 110 m. Survey effort at this locality was opportunistic searching for only two hours during late morning.

3. Series of swamps in forest habitat near the forest/savanna ecotone: Reserve de Faune de la Moukalaba-Dougoua, ± 5 km NW of Doussala, 02°19.24'S, 10°32.16'E, alt. 110 m. Survey effort at this locality was opportunistic searching for about 12 hours during two nights.

4. Forest habitat south of Camp 1: Reserve de Faune de la Moukalaba-Dougoua, 9–11 km 305° NW of Doussala, 02°17'S, 10°29'E, alt. 110 m. Survey effort at this locality formed part of that of Camp 1.

5. Université de Rennes Camp: Reserve de Faune de la Moukalaba-Dougoua, ± 11 km 305° NW of Doussala, 02°17'S, 10°29'E, alt. 110 m. Survey effort at this locality was haphazard over a period of 26 days and included pitfall trapping.

6. Camp 1. Forest habitat with small river: Reserve de Faune de la Moukalaba-Dougoua, 12.5 km 305° NW of Doussala, 02°17.00'S, 10°29.83'E, alt. 110 m. Survey effort at this locality was opportunistic searching during 11 days, including eight days of pitfall trapping, i.e., 88 trap-days.

7. Forest habitat north of Camp 1: Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 13–15 km NW of Doussala, 02°15'S, 10°29'E, alt. ± 110 m. Survey effort at this locality formed part of that of Camp 1.

8. Camp 2. Forest habitat with small river: Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW of Doussala, 02°13.35'S, 10°24.00'E, alt. 350–425 m. Survey effort at this locality was opportunistic searching during 8 days, including seven days of pitfall trapping, i.e., 77 trap-days.

9. Camp 3. Forest habitat on mountain peak. Start of mountain streams: Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 25.2 km 304° NW of Doussala, 02°13.63'S, 10°23.67'E, alt. 585–660 m. Survey effort at this locality was opportunistic searching during 8 days, including seven days of pitfall trapping, i.e., 77 trap-days.

10. No precise collecting information. Locality data entered in museum registers as: Reserve de Faune de la Moukalaba-Dougoua, NW of Doussala, 0210AD. A batch of reptile and amphibian specimens that were collected by Violaine Nicolas between March and October 2000.

MATERIALS AND METHODS

Three different camp sites, each located at a different altitude (110 m, 350–425 m and 585–660 m), were surveyed during February/March 2000. The basic approach to surveying reptile and amphibian communities along an elevational gradient follows that of similar studies conducted in Madagascar in recent years (e.g., Raxworthy and Nussbaum 1996; Raxworthy et al. 1998; Nussbaum et al. 1999).

Arrays of pitfall traps in combination with drift fences were erected as a passive capturing technique, which enabled quantitative comparisons to be made between the three different camp sites. Three trap lines were set in three different microhabitat types (e.g., in a valley bottom, on a slope, and along the crest of a ridge) at each camp. The only exception was at Camp 1, which had little topographical variation. Here we set two lines in the forest and one along a river margin. In addition to amphibians and reptiles, these traps were also capturing small mammals and arthropods.

A trap line consists of a 100-meter strip of plastic sheeting (drift fence) with sunken plastic buckets (pitfall traps) at 10 m intervals. Drift fences (0.5 m high) were stapled vertically onto wooden stakes. An apron left at the base was covered with soil and leaf litter to encourage individuals to move along the fence (towards the pitfalls) instead of trying to pass beneath it. The pitfall traps (275 mm deep, 285 mm top internal diameter, 220 mm bottom internal diameter) were sunk with their rims flush with ground level and positioned so that the drift fences ran across the middle of each trap. One pitfall trap was set at each

end of a drift fence with another nine traps spaced in between. Small holes (3–5 mm diameter) were burned in the base of buckets to allow for water drainage after rainfall events. Pitfall trap lines were set for eight days at Camp 1 and for seven days each at Camps 2 and 3 (see Table 1). The trap lines were checked each morning to collect amphibians and reptiles that may have fallen in during the night. Steve Goodman checked the lines again in the afternoons, but 99% of these times the traps contained no herpetological specimens. A trap-day is defined as one bucket in use for a 24-hour period. The daily capture rates of each trap line at each camp were calculated by dividing the total number of specimens collected during a trapping period by the number of trap-days (see Table 1). This formula for calculating daily capture rates followed the example of similar herpetofaunal and small mammal surveys (e.g., Raxworthy and Nussbaum 1996; Raxworthy et al. 1998; Nussbaum et al. 1999; Goodman and Hutterer, this volume). For comparisons of faunal uniqueness of the various sites, the species total of a particular site over the number of unique species for that site was calculated as a percentage. Coefficients of community (similarity indices) were determined as the number of shared species divided by the total number of species of the two localities being compared.

Active searches for specimens during day and night were made to supplement the pitfall efforts. Search techniques employed included visual scanning of terrain (using flashlight by night), refuge examination (e.g., lifting rocks and logs, peeling away bark, scraping through leaf litter) and tracking frog choruses. The bulk of the opportunistic sampling was conducted by Marius Burger, but additional specimens were also occasionally captured by other members of the biological inventory team: Patrice Christy, Brian Fisher, Steve Goodman and Simon van Noort.

At the time of our survey, a small mammal study incorporating the use of drift fences with pitfall traps was also being conducted by Station Biologique de Paimpont, Université de Rennes at site 5. This provided an opportunity to obtain further herpetological material from the region and Violaine Nicolas agreed to preserve samples of select individuals collected at this site (25 February to 21 March 2000). Although site 5 was located less than 1 km from Camp 1, the data obtained from there were not included in the species comparisons between Camps 1 to 3 since this would introduce an effort bias in the elevational species comparisons. Similarly, additional material subsequently collected by Nicolas between March and October 2000 (site 10) was not included. Although these have no precise collecting information, the data were added to the Monts Doudou herpetofaunal checklist.

Live specimens of most amphibian and reptile species collected during the survey were photographed to record color and patterning. These photographic slides are kept in M. Burger's private collection. Tape recordings of frog calls were collected for 23 species using a Sony TC-D5 PRO stereo cassette recorder. Individual calls were analyzed using Canary 1.2.4 and Sound Edit.

Representative voucher specimens were killed by placing tissue paper soaked with technical ether in an airtight plastic container with the animals. Chelonians and large snakes were killed by euthanasia injection. Specimens were fixed in a 10% formalin solution and were later transferred to alcohol for long-term storage. Liver and muscle tissue samples of almost all of the taxa collected were preserved in 95% ethanol for DNA analyses. Series of amphibian voucher specimens were deposited at the South African Museum (SAM) and reptiles in the Port Elizabeth Museum (PEM). These represent 257 (and 14 tadpoles) and 69 specimens respectively, and form the basis of the material discussed in this report. Duplicate material (ca. 200 specimens) will be deposited at a relevant institution in Gabon and at the California Academy of Sciences (CAS) and the Field Museum of Natural

History, Chicago (FMNH). On two occasions in this paper we make reference to material in the FMNH and once to a specimen in the Museum National d'Histoire Naturelle, Paris (MNHN).

The various families, subfamilies, genera, and species in the species accounts are presented alphabetically and do not reflect a phylogenetic arrangement. The nomenclature for many amphibian and reptile groups is still in a state of flux and consensus has not yet been reached between various workers. We generally follow Frost (2000) in respect to amphibian classification at the family, subfamily and genus levels, exceptions being our usage of *Xenopus* over *Silurana* (see Kobel et al. 1996) and *Amnirana* over *Rana* (see Dubois 1992). In the case of the reptiles we follow Broadley's (1998a) reptile checklist of the Democratic Republic of the Congo.

Identifications of amphibian species were based on descriptions in literature (Perret 1966, 1977, 1984; Lamotte 1967; Lamotte and Perret 1968; Laurent 1972; Amiet 1972, 1977, 1991, 2000; Schiøtz 1999) and comparisons of published sonograms (Tandy and Drewes 1985; Schiøtz 1999; Bosch et al. 2000; Márquez et al. 2000; Rödel 2000; De la Riva et al. 2001). Not all material was identified to the species level. This does not necessarily imply that such specimens represent undescribed taxa, although we believe that it does in some cases. Species identification in the genera *Hyperolius* and *Phrynobatrachus* is notoriously difficult because of the large numbers of valid species and synonyms that have been described (Poynton 1999; Frost 2000). Reptiles were identified from the literature, e.g., Loveridge 1939, 1947, 1958; Laurent 1950; Tys van den Audenaerde 1967; Brygoo and Roux-Esteve 1983; Rasmussen 1989; Lawson and Ustach 2000; Chippaux 2001.

This paper is primarily concerned with the species richness and variation in elevational distribution of amphibians and reptiles at Monts Doudou. For amphibians the details on species morphometrics, call structures, and descriptions of new taxa will be presented in forthcoming publications. For the reptile material we present details on scutelation, reproductive condition, hemipenal morphology, stomach contents and body proportions. Total lengths of specimens are presented as head-and-body length + tail length. Abbreviations used are SVL for measurement of snout vent length (same as head-and-body length) and TL for total length. MSR is midbody scale row count.

RESULTS

Summaries of the amphibian and reptile species recorded during the study are presented in Tables 1 and 2, respectively. The total numbers of species recorded from all ten sites are 54 amphibians and 32 reptiles. Of these, 34 amphibian and 17 reptile species were recorded from the elevational transect comprised of camps 1, 2, and 3.

A total of 726 pitfall trap-days yielded 263 amphibian captures and a daily capture rate of 36% (Table 3). The capture rate of amphibians decreased sharply from the lowest elevation up to the highest, with overall rates of 74.6% (197 specimens), 20.4% (47 specimens), and 8.2% (19 specimens) at camps 1, 2, and 3 respectively.

Seven species were collected in pitfall traps, 73% of which were of two species, i.e., *Xenopus epitropicalis* (138 specimens) and *Hemisus perreti* (53 specimens). High numbers of these two species were present in the traps following nights with good rainfall. *Hemisus perreti* was the only species not encountered during opportunistic sampling and the pitfall traps were thus important in recording the occurrence of this species. Likewise, more than 95% of *Xenopus epitropicalis* and about 90% of *Geotrypetes seraphini* specimens were from pitfall captures. Only one reptile, the Serrated Hinged Tortoise (*Kinixys erosa*), was

sampled by the pitfall traps, whereas the pitfall line set at the Université de Rennes camp (site 5) collected three skink species, i.e., *Mabuya affinis*, *M. polytropis* and *Leptosiaphos breviceps*. These species were also encountered during opportunistic searches and thus the pitfall traps were ineffective in boosting the total reptile species richness during this survey.

The amphibian species accumulation curves, incorporating the results of all sampling techniques, are presented in Figure 1. The cumulative species totals for Camps 1 and 2 were still increasing on the second to last and last day respectively, whereas no new species were added during the last three days at Camp 3.

The amphibian species richness figures recorded for the three camps are 21, 22, and 17 respectively, and comprise 34 species in total (Table 4). Of these, eight species were unique to Camp 1, six to Camp 2, and two to Camp 3 (see Table 4 and Figure 2). Camps 1 and 2 combined had 32 species, whereas Camps 2 and 3 totaled 26 species. Camp 1 shared 11 species with Camp 2 and 10 species with Camp 3. Camp 2 shared 13 species with Camp 3 and eight species were shared between all three camps.

Of the 53 frog species noted during this survey, 29 were observed calling and 22 of these were recorded on tape (see Table 1). In addition, a number of unidentified frog calls were noted at various localities. Some of these may belong to the 23 species for which no direct call observations were made, and/or they may belong to species that were not recorded during the survey.

TABLE 1. Checklist of amphibians (in alphabetical order) recorded from ten different localities at the Monts Doudou reserve comoplex. M - Museum specimen, T - Tape recording, H - Heard call (not taped), S - sight record.

Species	Localities									
	1	2	3	4	5	6	7	8	9	10
CAECILIANS										
Geotrypetes seraphini					M	M		M	M	
FROGS										
Acanthixalus spinosus		M								
Afrixalus fulvovittatus	MH									
Afrixalus sp. 1			MH							
Alexteroon obstetricans						M				
Amnirana amnicola								MT	M	
Amnirana lepus								M		
Arthroleptis variabilis					M				M	
Astylosternus batesi									MT	
Bufo camerunensis					M	M		M	M	
Bufo gracilipes					M					
Bufo maculates	MH									
Bufo tuberosus								M		
Cardioglossa gracilis					M	MT		M	T	
Cardioglossa leucomystax						MT		MT		
Cardioglossa sp. 1								MT	MH	
Chiromantis rufescens								MH		

TABLE 1. continued.

Species	Localities									
	1	2	3	4	5	6	7	8	9	10
Conraua crassipes						M	M	M	MH	
Dimorphognathus africanus						MH		MT	MT	
Hemisus perreti					M	M				
Hoplobatrachus occipitalis	M									
Hyperolius cinnamomeoventris	M		MT							
Hyperolius guttulatus			MT							
Hyperolius nasutus	M		MT							
Hyperolius ocellatus						MT		MT	MT	
Hyperolius tuberculatus			MT							
Hyperolius sp. 1			MT							
Hyperolius sp. 2			MT							
Hyperolius sp. 3			M							
Kassina sp. 1			T		M	M				
Leptopelis aubryi	MH									
Leptopelis calcaratus						MT			MH	
Leptopelis ocellatus								MT	MT	
Leptopelis millsoni						MT				
Leptopelis rufus								M		
Leptopelis sp. 1										M
Nectophryne batesii								M		
Petropedetes sp. 1								M	M	
Phlyctimantis leonardi			T							
Phrynobatrachus auritus					M	M				
Phrynobatrachus cornutus						M			M	
Phrynobatrachus sp. 1				M						
Phrynobatrachus sp. 2								T	MT	
Phrynobatrachus sp. 3			M							
Ptychadena aequiplicata					M					
Ptychadena perreti				S			M			
Ptychadena pumilio			MT							
Schoutedenella poecilonota					M	M		H	MT	
Schoutedenella sylvatica					M	MH		H	MT	
Scotobleps gabonicus								MH		
Trichobatrachus robustus								M		
Xenopus epitropicalis					M	M		M		
Xenopus fraseri							M			

TABLE 2. Checklist of reptiles recorded from ten different localities at the Monts Doudou reserve complex. M - Museum specimen, S - Sight record.

Species	Localities									
	1	2	3	4	5	6	7	8	9	10
LIZARDS										
Feylinia grandisquamis						M		M		M
Gerrhosaurus nigrolineatus	S									
Hemidactylus fasciatus					M	M		M	M	
Hemidactylus muriceus					M	M				
Hemidactylus cf. mabouia	S									
Leptosiaphos breviceps					M			M		M
Mabuya affinis				M	M		M			
Mabuya albilabris										M
Mabuya polytropis				M	M			M		
Rampholeon spectrum								M	M	
SNAKES										
Atheris squamigera								M		
Atractaspis corpulenta					M					M
Bitis gabonica										M
Boiga pulverulenta						M				
Bothropthalmus lineatus										M
Causus lichtensteini										M
Calabaria reinhardtii									M	
Crotaphopeltis hotamboeia							M			M
Dendroaspis jamesonii							S			
Dipsadoboa duchesnii			M						M	
Dipsadoboa weileri										M
Grayia ornata										M
Hapsidophrys smaragdina					M					
Mehelya capensis savorgnani										M
Mehelya guirali					M					
Naja melanoleuca						S?				M
Natriciteres fuliginoides								M		M
Philothamnus carinatus										M
Philothamnus sp. 1 *							M			
Rhamnophis aethiopissa										M
CROCODILIANS										
Crocodylus cataphractus			S							
CHELONIANS										
Kinixys erosa					M			M	S	
Pelusios castaneus	M									

* *Philothamnus* sp. 1 may be the same species as, or different from, *P. carinatus*. It was not included in the species richness tally.

TABLE 3. Details of trap line positions, trap dates, and capture results of amphibians and reptiles at Camps 1, 2, and 3 of the Monts Doudou-Moukalaba reserve complex.

Trap lines	CAMP 1			CAMP 2			CAMP 3		
	1	2	3	4	5	6	7	8	9
Altitude (m)	110			350–425			585–660		
First trap-day	24 February 2000			05 March 2000			14 March 2000		
Last trap-day	02 March 2000			11 March 2000			20 March 2000		
Total trap-days	88	88	88	77	77	77	77	77	77
					S				
AMPHIBIA									
Unidentified juvenile Arthroleptidae *	–	5	9	–	4	8	1	–	2
Bufo camerunensis	1	1	1	6	6	3	3	3	5
Geotrypetes seraphini	–	1	–	1	1	–	1	2	1
Hemisus perreti	5	30	18	–	–	–	–	–	–
Kassina sp. 1	1	–	1	–	–	–	–	–	–
Schoutedenella sylvatica	2	–	2	–	–	–	–	1	–
Xenopus epitropicalis	43	58	19	11	2	5	–	–	–
Total number of amphibian captures	52	95	50	18	13	16	5	6	8
Daily capture rate for amphibians	59.1%	108.0%	56.8%	23.4%	16.9%	20.8%	6.5%	7.8%	10.4%
Overall capture rate for amphibians	74.6%			20.4%			8.2%		
REPTILIA									
Kinixys erosa	–	–	–	1	–	2	–	–	–

* Unidentified juvenile Arthroleptidae specimens are presumed to include Schoutedenella poecilinotus and S. sylvatica.
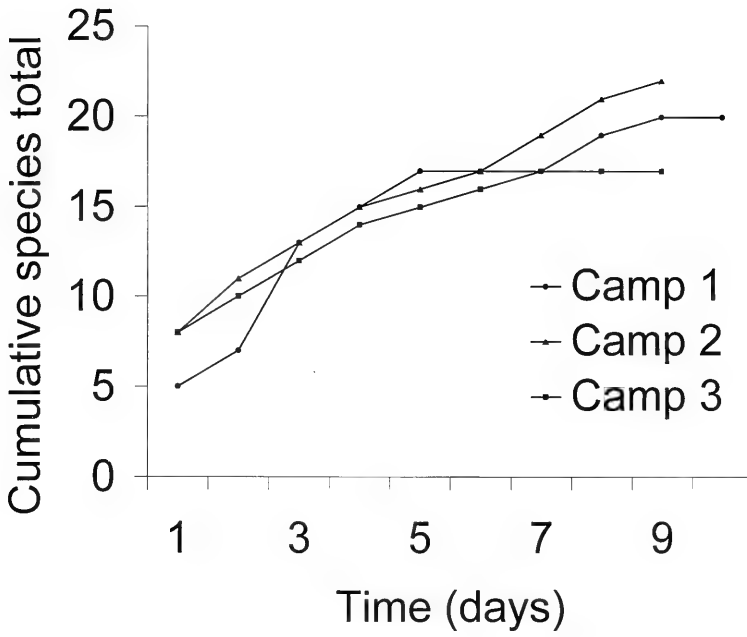
FIGURE 1. Species accumulation curves.
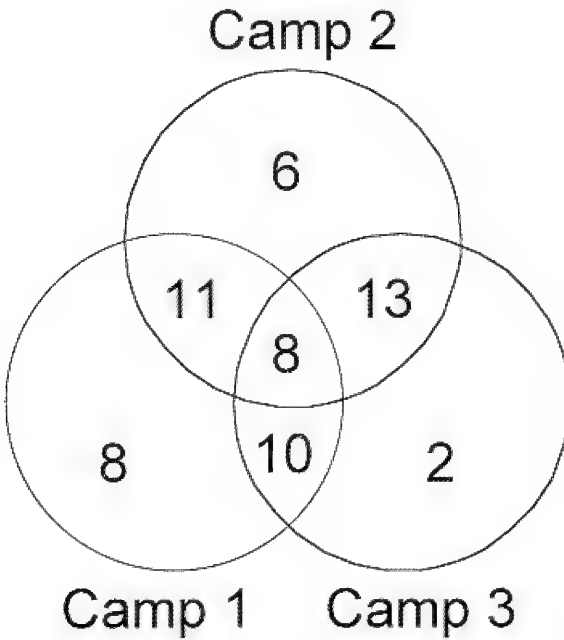
FIGURE 2. Graphic presentation of amphibian species richnes, turnover, similarity, and uniqueness between Camps 1, 2, and 3 of the Monts Doudou-Moukalaba reserve complex.

TABLE 4. Details of amphibian species turnover between Camps 1, 2, and 3. The first column lists the cumulative 34 species recorded from all three camps. The next three columns reflect species occurrence at these camps, followed by species uniqueness (U) at each camp and species shared (=) between camps. The last two columns show combined (+) species richness of Camps 1 and 2, and Camps 2 and 3 respectively. Note that Camp 1 consists of study sites 4, 6, and 7; Camp 2 is site 8 and Camp 3 is site 9.

Species - Amphibia	1	2	3	U1	U2	U3	1=2	1=3	2=3	1=2=3	1+2	2+3
Alexteroon obstetricans	1			1							1	
Amnirana amnicola		1	1						1		1	1
Amnirana lepus		1			1						1	1
Arthroleptis variabilis			1			1						1
Astylosternus batesi			1			1						1
Bufo camerunensis	1	1	1				1	1	1	1	1	1
Bufo tuberosus		1			1						1	1
Cardioglossa gracilis	1	1	1				1	1	1	1	1	1
Cardioglossa leucomystax	1	1					1				1	1
Cardioglossa sp. 1		1	1						1		1	1
Chiromantis rufescens		1			1						1	1
Conraua crassipes	1	1	1				1	1	1	1	1	1
Dimorphognathus africanus	1	1	1				1	1	1	1	1	1
Geotrypetes seraphini	1	1	1				1	1	1	1	1	1
Hemisus perreti	1			1							1	
Hyperolius ocellatus	1	1	1				1	1	1	1	1	1
Kassina sp.	1			1							1	
Leptopelis calcaratus	1		1					1			1	1
Leptopelis ocellatus		1	1						1		1	1
Leptopelis rufus		1			1						1	1
Leptopelis millsoni	1			1							1	
Nectophryne batesii		1			1						1	1
Petropedetes johnstoni		1	1						1		1	1
Phrynobatrachus auritus	1			1							1	
Phrynobatrachus cornutus	1		1					1			1	1
Phrynobatrachus sp. 1	1			1							1	
Phrynobatrachus sp. 2		1	1						1		1	1
Ptychadena perreti	1			1							1	
Schoutedenella poecilonota	1	1	1				1	1	1	1	1	1
Schoutedenella sylvatica	1	1	1				1	1	1	1	1	1
Scotobleps gabonicus		1			1						1	1
Trichobatrachus robustus		1			1						1	1
Xenopus epitropicalis	1	1					1				1	1
Xenopus fraseri	1			1							1	
TOTALS	20	22	17	8	7	2	11	10	13	8	32	26
RELATIVE PERCENTAGE				40.0	31.8	11.8					94.1	76.5

156

SPECIES ACCOUNTS

Order Anura: Family Arthroleptidae: Genus *Arthroleptis*

The Frétey and Blanc (2000) list of Gabon amphibians does not distinguish between the genera *Athroleptis* and *Schoutedenella*, nor does Poynton's (1999) list for Sub-Saharan Africa. As a taxonomic unit this group is reputably problematic with 33 recognized species (Poynton 1999) and numerous synonyms (Frost 2000). Future studies endeavoring to sort out this enigmatic complex should place emphasis on recording call data. Five *Arthroleptis* species are listed for Gabon (Frétey and Blanc 2000), but three of these may be treated as being members of *Schoutedenella*. We recorded only one species of *Arthroleptis*.

Arthroleptis variabilis Matschie 1893

SAM 51006–9, 51060. Sites 5 and 9. A single specimen was collected at site 5, whereas the remaining four specimens were found active during the day in leaf litter right at the top of the mountain. Two small, unidentified snails were present in the stomach of SAM 51009.

Genus *Cardioglossa*

Frétey and Blanc (2000) listed two *Cardioglossa* species from Gabon and they listed another two species (*C. escalarae* and *C. gratiosa*) that may occur here. We confirmed the occurrence of *C. gracilis* and *C. leucomystax* in Gabon and recorded another, as yet unidentified, species.

Cardioglossa gracilis Boulenger 1900

SAM 50962–66, 51035. Sites 5, 6, 8, and 9: A common species throughout the elevational range.

Cardioglossa leucomystax (Boulenger 1903)

SAM 50970–72, 51036. Sites 6 and 8: Recorded from lower and middle elevational ranges.

Cardioglossa sp. 1

Fig. 3. SAM 50967–69, 51031. Sites 8 and 9: Tape recordings of calling males were made at Camp 1 and a total of four specimens were collected. Further comparisons with literature and various type material are needed before a positive identification can be made.

Genus *Schoutedenella*

See general discussion under the *Arthroleptis* account above. We could identify two species from the Monts Doudou material, but more may possibly be present. It is particularly difficult to identify juvenile specimens.

Schoutedenella poecilonota (Peters 1863)

SAM 51176–79. Sites 5, 6, 8, and 9: Present throughout the elevational range.

Schoutedenella sylvatica Laurent 1954

SAM 51203–10. Sites 5, 6, 8, and 9: Present throughout the elevational range.

Schoutedenella sp. 1

SAM 51211–18. Sites 5 and 6: These specimens may represent a different taxon or they could be juveniles of *S. poecilonotus*. We have assumed the latter and have included pitfall capture records of these specimens with that of *S. poecilonotus* and we do not list it as an additional species for this region (see Table 2).

Family Astylosternidae: Genus *Astylosternus*

Poynton (1999) listed 11 species for Sub-Saharan Africa. Only *A. batesi* is known from Gabon (Frétey and Blanc 2000).

Astylosternus batesi (Boulenger 1900)

SAM 51076–79. Site 9: This species was only found along small streams at the highest elevations.

Genus *Scotobleps*

A monotypic genus with previous records from Gabon (Frétey and Blanc 2000).

Scotobleps gabonicus Boulenger 1900

SAM 51003–5, 51034. Site 8: A few specimens were calling from the riverbank at Camp 2.

Genus *Trichobatrachus*

A monotypic genus not previously recorded from Gabon according to Frétey and Blanc (2000). In addition to our Monts Doudou record, *Trichobatrachus robustus* was recently also recorded from Gabon by Lötters et al. (2000) and Lötters et al. (2001). A specimen (FMNH 75058) in the Field Museum of Natural History, Chicago, was collected in Gabon by H. A. Beatty on 14 September 1951.

Trichobatrachus robustus Boulenger 1900

SAM 50950. Site 8: A single adult male was collected sitting on riverbank at night. No other specimens were observed.

Family Bufonidae: Genus *Bufo*

According to Poynton's (1996) scale for mapping African *Bufo* species diversity, four to six species are known from the five-degree grid cell in which Monts Doudou is situated. Frétey and Blanc (2000) listed eight species of *Bufo* from Gabon. We recorded four of these during our survey.

Bufo camerunensis Parker 1936

SAM 51224–34. Sites 5, 6, 8, and 9: A common species throughout the elevational range, but none were observed calling.

Bufo gracilipes Boulenger 1899

SAM 51221–23. Site 5: Three specimens were captured in pitfall traps.

Bufo maculatus Hallowell 1855 "1854"

SAM 51197–51201. Site 1: This species was not encountered in the forest localities, i.e., sites 2 to 9. It was, however, quite common in savanna habitat at Doussala where it was observed calling.

Bufo tuberosus Günther 1859 "1858"

SAM 51044. Site 8: A single adult specimen was collected in leaf litter. Photo in Burger (2002).

Genus *Nectophryne*

Both of the species that make up the genus *Nectophryne* have been recorded from Gabon (Frétey and Blanc 2000). We recorded only *N. batesii*. Poynton's (1996) map of non-*Bufo* African bufonids projects 5 to 6 species of the *Nectophryne* group occurring in the five-degree grid cell which covers northern Gabon and Cameroon, but none are recorded for the grid cell which covers Monts Doudou.

Nectophryne batesii Boulenger 1913

AM 51063–64. Site 8: The only two individuals found during the survey were collected incidentally by Brian Fisher whilst beating branches for ants and by Simon van Noort whilst sweeping through foliage with a net to collect insects.

Family Hemisotidae: Genus *Hemisus*

According to Laurent (1972) and Frétey and Blanc (2000), no members of the Hemisotidae are known to occur in Gabon.

Hemisus perreti Laurent 1972

Fig. 4. SAM 50947–48, 50951–61, 51051. Sites 5 and 6: We captured 53 individuals in pitfall traps set at Camp 1. Captures were always associated with periods of substantial rainfall.

Family Hyperoliidae: Subfamily Hyperoliinae: Genus *Acanthixalus*

A monotypic genus known from Bioko, Cameroon, Equatorial Guinea, Gabon, Congo, and DRC (Frétey and Blanc 2000).

Acanthixalus spinosus (Buchholz and Peters 1875)

SAM 51058, 51220. Site 2: A sample of 14 tadpoles (SAM 51220) at various stages of development were collected from a water-filled, tree hole on 29 February 2000. Total lengths of tadpoles measured between 29 and 52 mm. A few eggs (<10) were hanging from a jelly strand at the tree hole entrance. Only one tadpole had well-developed hind legs when collected. This individual was kept alive until it completed metamorphoses 10 days later at which time it was photographed and preserved (SAM 51058).

Genus *Afrixalus*

Four species of *Afrixalus* are known from Gabon (Frétey and Blanc 2000). We recorded one of these, *A. fulvovittatus*, and another that could not be identified.

Afrixalus fulvovittatus (Cope 1861 "1860")
SAM 51010–13, 51056. Site 1: Males were observed calling from grass stalks in marshy habitat. The coloration and patterning of these individuals conform with the *A. fulvovittatus* (type B) descriptions in Schiøtz (1999).

Afrixalus sp. 1
SAM 51014–17, 51055. Site 3: Specimens were observed calling from grass and other low vegetation at fringes of marsh. Unfortunately the tape-recording made for this species was spoiled. This species does not fit any of the descriptions of the Afrixalus species recognized by Schiøtz (1999).

Genus *Alexteroon*

The genus *Alexteroon* was monotypic with *A. obstetricans* as the type species. However, two new species were recently described by Amiet (2000). One of the new species, *A. hypsiphonus*, is known from a few Gabon localities and the probable occurrence of *A. obstetricans* in Gabon was anticipated (Amiet 2000). Our record from southwestern Gabon confirms Amiet's prediction.

Alexteroon obstetricans (Ahl 1931)
SAM 51026. Site 6: One individual was collected by Steve Goodman who found it at night climbing about a wooden pole from which a mistnet was set. Its coloration and patterning conforms well with the illustration of *A. obstetricans* in Schiøtz (1999: 86). First record of this species from Gabon.

Genus *Hyperolius*

Hyperolius contains 90 species in Sub-Saharan Africa, making it the anuran genus with the greatest number of species in this region (Poynton 1999). Only eight species are listed from Gabon by Frétey and Blanc (2000), but Lötters and colleagues (2001) added *H. mosaicus* and provided apparently the first proven records for *H. phantasticus* and *H. pardalis*. Eight species were recorded during the Monts Doudou survey. Two of these, *H. guttulatus* and *H. nasutus*, are new for Gabon and another two (possibly three) appear to be undescribed taxa.

Hyperolius cinnamomeoventris Bocage 1866
SAM 51188–96. Sites 1 and 3: A common species at marshy habitats. A female was observed during the day clutching an egg-mass attached to herbaceous vegetation growing in shallow water.

Hyperolius guttulatus Günther 1858
Fig. 5. SAM 51027–30. Site 3: A conspicuous species observed calling from floating vegetation and up to a meter above the water's surface. First record of this species for Gabon.

Hyperolius nasutus Günther, 1865 "1864"
Fig. 6. SAM 51162–68. Sites 1 and 3: Observed calling from thin reeds on the edge of swamps in savanna and forest/savanna ecotone. Not listed by Frétey and Blanc (2000) and thus appears to be the first record of this species from Gabon. Species identification is based on an assessment of advertisement calls within the *H. nasutus* complex (Channing et

al. 2002). According to this study the material from Kouilou River basin in the Congo (Largen and Dowsett-Lemaire 1991) are also referable to *H. nasutus*.

Hyperolius ocellatus Günther 1859 "1858"
    SAM 50992, 50994–95, 51053, 51131. Sites 6, 8, and 9: A common species at all three elevational sectors. Males were observed calling from leaves and thin branches 1 to 3 m up in trees. This species is strongly sexually dimorphic with females being considerably larger and completely different in color and patterning.

Hyperolius tuberculatus Mocquard 1897
    SAM 51018–22. Site 3: A common species at site 3. Males were calling lowdown from trees adjacent to marshy habitat.

Hyperolius sp. 1
    Fig. 7. SAM 51023–25. Site 3: This species superficially resembles *Hyperolius bobirensis* Schiøtz 1967 and *H. zonatus* Laurent 1958 in respect to coloration and patterning. However, the call is very different from those species and we believe that our specimens may in fact represent an undescribed taxon. A few individuals were observed calling from emergent vegetation.

Hyperolius sp. 2
    Figs. 8 and 9. SAM 51156–57. Site 3: A small *Hyperolius* which could not be identified by us. Tape recordings of calling males were taken.

Hyperolius sp. 3
    SAM 51158–61. Site 3: A small series of what appears to be another undescribed species of *Hyperolius* was collected at site 3, but vocalizations were not heard.

Subfamily Kassininae: Genus *Kassina*
No *Kassina* species were known from Gabon (Frétey and Blanc 2000).

Kassina sp. 1
    Fig. 10; see also color illustration in Burger (2002b). SAM 51065–75. Sites 5 and 6: Fifteen individuals were collected in pitfall traps at site 5 and two individuals were collected in pitfall traps at Camp 1. These appear to be all females. Calling *Kassina* males were recorded at site 3, but unfortunately no individuals were observed to link these calls with the taxon collected at sites 5 and 6. Surprisingly these records seem to be the first for *Kassina* from Gabon.

Genus *Phlyctimantis*
    Of the four recognized species in this genus (Poynton 1999), only *P. leonardi* has been recorded from Gabon (Frétey and Blanc 2000). However, Lötters and colleagues (2001) consider their material to be *P.* cf. *boulengeri* instead.

Phlyctimantis leonardi (Boulenger 1906)
    Site 3: Although no individuals were directly observed, the tape recordings made of a chorus at site 3 confirms the occurrence of this species at the study area. The Monts Doudou recordings agree with some made at Pointe Ngombe, at Ekwata, 16 km 240° WSW of Libreville, 00°19.58′N, 09°18.92′E (M. Burger pers. observ., 26 March 2000). Species

FIGURE 3. *Cardioglossa* sp. 1, recorded from Camps 1 and 2.

FIGURE 4. *Hemisus perreti*, first record of Hemisotidae from Gabon.

FIGURE 5. *Hyperolius guttulatus*, first record of this species in Gabon.
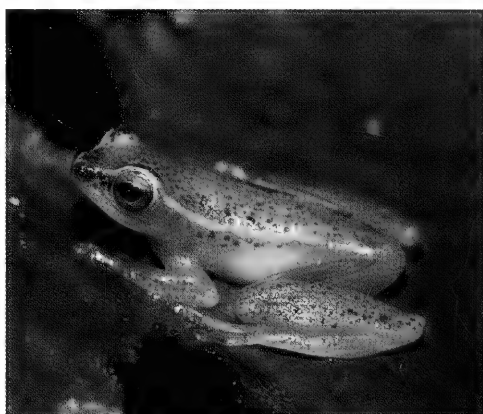
FIGURE 6. *Hyperolius nasutus*, first record of this species in Gabon.

identification at Ekwata was verified when calling males were photographed and specimens examined.

Subfamily Leptopelinae: Genus *Leptopelis*

Frétey and Blanc (2000) listed 10 *Leptopelis* species from Gabon. We recorded five of these and one other which must still be identified.

Leptopelis aubryi (Duméril 1856)

SAM 50986–87, 51033. Site 1: A few individuals were observed at Doussala calling from reeds and low herbaceous vegetation in marshy habitat.

Leptopelis calcaratus (Boulenger 1906)

SAM 51089–93, 51169. Sites 6 and 9: The calls of this species were heard every night at Camp 1. Males of this species called from 5 m up or higher in trees. It was not recorded at the mid-elevation camp. At Camp 1 individuals called within meters from calling *Leptopelis millsoni*.

FIGURE 7. *Hyperolius* sp. 1, unidentified species, which appears to be an undescribed taxon.
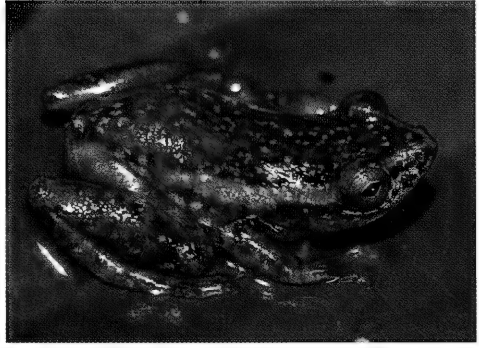
FIGURE 8. *Hyperolius* sp. 2, color variation in male.

FIGURE 9. *Hyperolius* sp. 2, color variation in male.

FIGURE 10. *Kassina* sp. 1, first record of this genus for Gabon.

Leptopelis ocellatus (Mocquard 1902)

SAM 50982–85, 51083. Sites 8 and 9: Specimens were observed calling from between 1 and 3 m up in trees along streams. Color photo of Monts Doudou specimen was published in Burger (2002b).

Leptopelis millsoni (Boulenger 1895 "1894")

SAM 51087–88. Site 6: Males called from 5 m up and higher in trees every night at Camp 1.

Leptopelis rufus (Reichenow 1874)

SAM 51085–86. Site 8: Two individuals found on branches along river at Camp 2. Color photo of SAM 51085 in life was published in Burger (2002a). No calling was heard for this species.

Leptopelis sp. 1

SAM 51394. Site 10: A single individual, collected after the survey period, still needs to be identified.

Family Petropedetidae: Genus *Dimorphognathus*
The recognition of a Petropeditidae is likely to be dropped by future workers, but is retained here for the sake of consistency in following Frost (2000). *Dimorphognathus* is a monotypic genus with previous records from Gabon (Frétey and Blanc 2000).

Dimorphognathus africanus (Hallowell 1857)
SAM 51170–75. Site 6, 8, and 9: The conspicuous calling of this frog was heard every day at all three camps.

Genus *Phrynobatrachus*
Phrynobatrachus has the second largest number of species in the African anura with 65 Sub-Saharan species (Poynton 1999) and still more being described (e.g., Drewes and Perret 2000). Only five species are known from Gabon (Frétey and Blanc 2000). The Monts Doudou material also comprises five species, but only two were positively identified by us. The remaining three species must still be compared with other museum voucher specimens before final identifications are made.

Phrynobatrachus auritus Boulenger 1900
SAM 50996–51001, 51037–39. Sites 5 and 6: Collected opportunistically at Camp 1, but several individuals were also captured in pitfall traps at site 5.

Phrynobatrachus cornutus (Boulenger 1906)
SAM 51184–87. Sites 6 and 9: All individuals were collected from leaf litter during opportunistic searches.

Phrynobatrachus sp. 1
Fig. 11. SAM 51182–83. Site 4: Two male individuals were collected from leaf liter whilst active during the day.

Phrynobatrachus sp. 2
Fig. 12. SAM 50988–91, 51061. Site 8 and 9: A small, vividly marked species found in muddy terrain near small streams. Males were observed and taped whilst calling during the day and at sunset.

Phrynobatrachus sp. 3
Fig. 13. SAM 51081–82. Site 3: A common, seemingly diurnal, species observed in association with shallow swamp habitat.

Genus *Petropedetes*
Up until recently *Petropedetes newtoni* was the only representative of this genus from Gabon (Frétey and Blanc 2000). However, Lötters and colleagues (2001) recorded another two species (*P. palmipes* and *P. parkeri*). The Monts Doudou material appear to be different from these three species.

Petropedetes sp. 1
Fig. 14. SAM 51002, 51052, 51181. Sites 8 and 9: Two adults and one juvenile were collected during nocturnal searches, but none were heard calling.

Family Pipidae: Subfamily Xenopodinae: Genus *Xenopus*

Our use of the genus *Xenopus* instead of *Silurana* (see Cannatella and Trueb 1988) follows Kobel et al. (1996). The Monts Doudou material included two of the three *Xenopus* species listed by Frétey and Blanc (2000). They also listed *X. andrei* and we add *X. sudanensis* for Gabon.

Xenopus epitropicalis Fischberg, Colombelli and Picard 1982

SAM 51134–50, 51155. Sites 5, 6 and 8: Although this was by far the most common species captured in the pitfall traps (138 in total), it was very seldom encountered in its natural habitat. A few individuals were observed in shallow mud pools on the forest floor.

Xenopus fraseri Boulenger 1905

SAM 51151. Site 7: A single individual was found in a water-filled elephant spoor.

Xenopus sudanensis Perret 1966

SAM 51123. Site 3: An adult was collected from a shallow pond. This taxon is new for Gabon.

An individual (SAM 51219) of what may be a fourth species of *Xenopus* was collected from a small dam at Doussala (site 1). The specimen is a newly metamorphosed juvenile, therefore identification is difficult.

Family Ranidae: Genus *Amnirana*

Three species are known from Gabon (Frétey and Blanc 2000), but we did not record *Amnirana albolabris*.

Amnirana amnicola (Perret 1977)

SAM 51098–109. Sites 8 and 9: A very common species that was often observed on vegetation adjacent to small streams. Males were occasionally heard calling at night.

Amnirana lepus (Andersson 1903)

SAM 51094–97. Site 8: Only four individuals were encountered during opportunistic searches at Camp 2.

Genus *Conraua*

Six species are recognized in this genus (Frost 2000), but only *Conraua crassipes* is known from Gabon (Frétey and Blanc 2000).

Conraua crassipes (Buchholz and Peters 1875)

SAM 51110–22, 51130. Sites 6, 7, 8, and 9: Patrice Christy identified the characteristic call of this species at site 9. Specimens were most often observed at night on rocks in slow- and fast-flowing streams. An individual was also found in a shallow muddy pool more than 100 m away from any streams.

Genus *Hoplobatrachus*

Not listed for Gabon by Frétey and Blanc (2000), but recently recorded by Lötters et al. (2001). A specimen (FMNH 75061) in the Field Museum of Natural History, Chicago,

FIGURE 11. *Phrynobatrachus* sp. 1, found in leaf litter at site 4.

FIGURE 12. *Phrynobatrachus* sp. 2, called during the day at Camps 2 and 3.

FIGURE 13. *Phrynobatrachus* sp. 3, from marshy habitat at site 3.

FIGURE 14. *Petropedetes* sp. 1 from Camp 2.

was collected in Gabon by H. A. Beatty on 21 August 1951, but this record was never published.

Hoplobatrachus occipitalis (Günther 1859 "1858")

SAM 51045–46. Site 1: A common species observed in association with small dams in and around Doussala village.

Genus *Ptychadena*

Six species of *Ptychadena* are known from Gabon (Frétey and Blanc 2000), three of which were recorded during the Monts Doudou survey.

Ptychadena aequiplicata Werner 1898

SAM 51057. Site 5: A single individual was collected by Violaine Nicolas.

Ptychadena perreti Guibé and Lamotte 1958

SAM 51062. Site 4 and 7: A few individuals were observed in damp grassy habitat at forest fringes along an old logging road.

Ptychadena pumilio (Boulenger 1920)

SAM 51059. Site 3: A single individual was taped whilst calling from the edge of a marsh. No other individuals were observed. This species was referred to as *Ptychadena taenioscelis* by Largen and Dowsett-Lemaire (1991).

Family Rhacophoridae: Subfamily Rhacophorinae: Genus *Chiromantis*

Schiøtz's (1999) distribution map for *Chiromantis rufescens* shows no records for Gabon, but it is listed by Frétey and Blanc (2000).

Chiromantis rufescens (Günther 1868)

SAM 50949, 51042. Site 8: A few foam nests were observed on vegetation overhanging a small muddy pool in the forest (P. Christy pers. comms., 8 March 2000). This locality was visited again on 12 March at night during which time a few males were collected from adjacent vegetation. Surprisingly, no observations of this species were made at any of the other sites.

SPECIES ACCOUNTS

REPTILIA

Species accounts start with specimen accession numbers (PEM R = Port Elizabeth Museum), followed by the various localities (sites 1–9) at which a particular species was recorded. The MB accession numbers are for specimens that will be deposited in a Gabon collection.

Suborder Sauria: Family Chamaeleonidae: Genus *Rhampholeon*

Only one chameleon species was recorded during this survey. A number of species in the genus *Chamaeleo* (e.g., *C. oweni* and *C. cristatus*) may also be expected in the region.

Rampholeon spectrum (Buchholz 1874)

PEM R 15697–98, 15700–1. Sites 8 and 9: Three individuals were found at night sleeping on vegetation about 50 cm high; two were also collected during the day. The single female (PEM R 15697, 57 + 16 mm) contained two large ova (8–9 mm diameter) and a large grasshopper in the stomach. Three adult males (largest 56 + 23 mm) have well-everted hemipenes.

Wild (1994), describing ecological observations on *R. spectrum* from Cameroon, noted maximum snout-vent lengths of 57 mm and 58 mm for female and males, respectively. The roosting sites of the Monts Doudou specimens also conform to Wild's observation (1994), that noted that 91% of night-time roosts were below 100 cm. Grasshoppers were rare in the diet (one record out of 32) of Cameroon *R. spectrum* (Wild 1994). The two large ova in the Monts Doudou female conform to the typical clutch of two eggs recorded elsewhere (Wild 1994).

In a review of hemipenial morphology in the Chamaeleonidae, Klaver and Böhme (1986) noted that the hemipenis of *R. platyceps* (Malawi) lacked calyces. For Cameroon *R. spectrum* they noted that the hemipenes were "like those of the previous species, but instead of apical horns there are two complex apical projections." These are denticulate flanges that comprise a main flange, with seven denticles on the crest and 2–3 additional denticles on the lateral surface and a smaller flange with up to five denticles. The morphology of the Monts Doudou material differs in details from Klaver and Böhme's (1986) de-

scription. Unlike the inference that *R. spectrum* lacks calyces, all the Gabon everted hemipenes display well-developed, fine lateral flounces on the asulcal surface. These anastamose to calyces distally. The sulcus spermaticus drains into a large apical V-shaped nude basin [also unrecorded by Klaver and Böhme (1986) in Cameroon material], which at the outer tips of the arms bears complex denticulate flanges. These differ in the number of denticles from those recorded for Cameroon material. Denticles on the main flange vary from 10–12 (mean 10.75), on the lateral surface of the main flange from 2–3 (mean 2.4), and on the smaller flange from 6–7 (mean 6.17). Denticle counts on both flanges are significantly higher than those recorded for Cameroon materal. Although hemipenial morphology is useful in *Rhampholeon* systematics (Tilbury and Emmrich 1996), caution is necessary in assessing the taxonomic significance of the observed difference between Monts Doudou and Cameroon material. Bryoo and Domergue (1971) and Böhme (1988) have both noted seasonal variation in hemipenial ornamentation in chameleons. The higher denticle counts in Monts Doudou males may therefore reflect seasonal differences between the populations. However, Wild (1994) noted breeding throughout the year in Cameroon, and similar aseasonal breeding is likely in Monts Doudou. The taxonomic significance of these hemipenial differences between Gabon and Cameroon populations needs further investigation.

Family Gekkonidae: Genus *Hemidactylus*

Hemidactylus fasciatus Gray 1842

PEM R 15699, 15707, 15711, 15713. Sites 5, 6, 8, and 9: These large forest geckos were encountered at night about 1.5 m up on trees with smooth trunks, on all occasions in a head-down position. A large male with original tail (78 + 96 mm) has mature, active testis. Two of the three females are gravid, each with a single egg (12 × 9–10 mm) in each oviduct. The largest female had a SVL 84 mm. A non-gravid female had a full stomach containing the remains of a large centipede, small millipede and large grasshopper. Schmidt (1919) recorded a maximum female SVL of 77 mm, but with an exceptional male reaching 95 mm SVL.

Hemidactylus muriceus Bocage 1873

PEM R 15691–92. Sites 5 and 6: Two individuals were collected during opportunistic searches. A large female (49 + 43 mm) contains two developing ova (4.5 mm diameter). The male (41 + 45 mm) has well-developed hemipenial bulges but only eight preanal pores.

The taxa *H. muriceus, H. ansorgei, H. echinus*, and *H. longicephalus* are difficult to distinguish (Schmidt 1919; Loveridge 1947; Dunger 1968), and Böhme (1975) has noted that *H. longicephalus* and *H. ansorgei* are probably best treated as synonyms of *H. muriceus*. *Hemidactylus echinus* can also be confused with *H. muriceus*, but can be distinguished by its digital webbing, denser tuberculation including the presence of two rows of subcaudal tubercles, and higher subdigital counts (Loveridge 1947). The complex is in need of a modern revision, and the present specimens are provisionally referred to *H. muriceus* on the basis of the lack of obvious digital webbing; sparse and irregular dorsal tubercles (which at most forms 11–13 poorly defined rows); presence of only one internasal granule; number of scansors under the first (6–7) and fourth toe (8–10); lack of subcaudal tubercles; the light scattering of brown infusions on the ventrum; and rain forest habitat.

Hemidactylus cf. *mabouia* (Moreau de Jonnès 1818)

Site 1: Another species of *Hemidactylus* (cf. *H. mabouia*) was observed on buildings in the Doussala village. One individual was captured, but unfortunately managed to escape later. Future surveys in this region should endeavor to collect voucher material of this gecko species.

Family Gerrhosauridae: Subfamily Gerrhosaurinae: Genus *Gerrhosaurus*

Lang (1991) presented a phylogenetic study supporting recognition of the familial status of the Gerrhosauridae within Cordyliformes, and separation of the African Gerrhosaurinae from the Madagascan sister taxon Zonosaurinae. However, Odierna and colleagues (2002) have presented additional molecular and chromosomal evidence that genetic divergence in Cordyliform lizards is low. They recommend only subfamilial status for plated lizards within the Cordylidae. Because these relationships remain unresolved and are the subject of ongoing studies, we provisionally retain the use of familial status.

Gerrhosaurus nigrolineatus Hallowell 1857

Site 1: Four individuals were observed dashing across bush paths in savanna habitat, but unfortunately none could be captured.

The *Gerrhosaurus nigrolineatus* complex is in need of revision (Broadley *in litt.* November 2000). The type locality of *G. nigrolineatus* is Gabon, and populations south and east, previously referred to *G. nigrolineatus*, may best be referable to another taxon.

Family Scincidae: Subfamily Feyliniinae: Genus *Feylinia*

Greer (1970) stabilized the scincid subfamilial relationships, and recognized the Feyliniinae containing the genera *Feylinia* and *Chabanaudia*. Brygoo and Roux-Esteve (1983) subsequently placed *Chabanaudia* in the synonymy of *Feylinia*. In their revision of the genus, Brygoo and Roux-Esteve (1983) recognized six species, validating four species previously placed in synonymy. Three species are currently recognized from Gabon; the wide-ranging species *Feylinia currori* and *F. grandisquamis*, and the minute (<100 mm TL) *F. boulengeri*, which is endemic to Gabon. Brygoo and Roux-Esteve (1983) differentiated *F. grandisquamis* from *F. currori* solely by the number of midbody scale rows (MSR 19–21 vs. 23–28, respectively) and size (<200 mm TL vs. >300 mm TL, respectively). The Monts Doudou material has 21 MSR and an adult size of <200 mm, and is thus referable to *F. grandisquamis*. Further studies of species boundaries within the genus, preferably supported by genetic analysis, are needed. The biology and distribution of these unusual burrowing skinks also remains poorly known.

Feylinia grandisquamis Müller 1910

PEM R 5242–44, 15712, 15694–95. Sites 6, 8, and 10: Two individuals were found in leaf litter and a third behind a termitarium that was constructed against a tree trunk. Surprisingly, no individuals were collected in pitfall traps. Both females were gravid; one (116 + 63 mm) contained a single large egg (14–15 × 6 mm) in each oviduct, without discernable embryos; the other (120 + 43 mm) also contained an egg (21 × 10 mm) in each oviduct, one of which contained a well-developed embryo (approximate TL 30–40 mm). The hemipenis of the male (PEM R 15694) is everted; it is simple with the sulcus spermaticus draining into two small apical cups that are separated by a prominent apical flap; the base and sulcal folds are nude; the asulcal surface of the apical flap bears shallow papillate flounces.

Brygoo and Roux-Esteve (1983) listed only two other localities (Ogouma and Alima Leketi) for *F. grandisquamis* in Gabon.

Subfamily Lygosominae: Genus *Mabuya*

Hoogmoed (1974) reviewed Ghanian *Mabuya*, discussing species from the adjacent Congo basin, including Gabon. He validated *M. albilabris*, previously considered a synonym of *M. blandingii*, as a good species, and also showed that *M. affinis* (Gray 1838) had priority over *M. blandingii* (Hallowell 1844).

Mabuya affinis (Gray 1838)

PEM R 15715, 15720, 15722–23, MB 5070, 5122. Sites 4, 5, and 7: A few individuals were observed during the day on fallen trees and on the ground along an old logging road. Five eggs found under a stone hatched on 22 March 2000. Two of the hatchlings measured 26 + 41 mm and 26 + 45 mm. The largest male had a SVL 78 mm; the other had an original tail, 67 + 130 mm. Previous maximum male size had been 76 mm (Ghana and Ivory Coast; Hoogmoed 1974). Both males were sexually mature with well-developed, active testes. The largest had a well-everted hemipenis of unusual structure. The organ was divided for half its length, with the sulcus spermaticus dividing in the crotch. The arms had three, thick, unornamented longitudinal ridges that give them a triangular cross-section. Along one of the ridges on each arm a fork of the sulcus runs to the tip, where two small papillae occur. Between the ridges on the arms run parallel, shallow horizontal flounces. Hoogmoed (1974) noted earlier Gabon specimens from Benito River and Mitzii (= Mitzic ?).

Mabuya albilabris (Hallowell 1857)

PEM R 5245–50. Site 10: Although similar to, and easily confused with *M. affinis*, the Monts Doudou material confirms Hoogmoed's (1974) diagnostic features separating the two species; i.e., only one scale between the fourth suprocular and the anterior supratemporal (two in *M. affinis*), and lower subdigital lamellae counts. Hoogmoed (1974) also noted that a pale lateral body stripe (yellowish in life) may or may not be present. It is now evident that this is due to sexual dimorphism. Analysis of additional Gabon material from Gamba and Rabi revealed that the pale lateral line is present in juveniles and mature females (67–71 mm SVL), but absent in sexually mature males (65–70 mm SVL). The latter develop a dark brown rusty infusion to the dorsum and a bright lime yellow ventrum. A prominent rust red spot occurs on the side of the neck in front of the forelimbs, and the throat is bright grey with dark-emargined scales.

Of three large females (67–71 mm SVL), two were gravid, PEM R 5248 containing two enlarged ova (5 mm diameter) and PEM R 5250 with three fully developed eggs (13–14 ×8–9 mm). The latter had thickened shells, but no sign of embryonic development. An additional Gabon female from Gamba also had two large eggs without embryonic development. Therefore it is probable that the species is oviparous, supporting Hoogmoed's (1974) supposition. The species inhabited forest floor, and this is reflected in the gut contents, which included mostly grasshoppers (four stomachs), with a large spider in another. The stomach of a large male (65 mm SVL) also contained a juvenile *Mabuya albilabris*, the first record of cannibalism in the species.

Mabuya polytropis Boulenger 1903

PEM R 5251, 15714, 15717, 15719, 15721. Sites 4, 5, 8, and 10: Observed on fallen trees during daytime. Both large females were gravid; PEM R 15719, 83 mm SVL, con-

tained 2 + 2 large eggs (16 × 9 mm) ready for laying; PEM R 15714, 85 mm SVL, contained 2 + 1 smaller eggs (6 mm diameter). A smaller male (65 mm SVL) had immature testes; the stomach contained the body of a large spider. The stomach of an immature female contained two mole crickets.

Genus *Leptosiaphos*

Leptosiaphos breviceps (Peters 1873)

PEM R 5267–68, 15716, 15718. Sites 5, 8, and 10: Collected in pitfall traps at site 5 and in leaf litter at Camp 2. The large female (53 mm SVL) contained 2 + 1 eggs (11 × 6 mm) that appear ready for laying. Two females were gravid: one (53 mm SVL) contained 2 + 1 eggs (11 × 6 mm) that appeared ready for laying; another (59 mm SVL) contained a single enlarged (4 mm diameter) ovum in each oviduct. A large male (61 mm SVL) is sexually mature, with large active testes. As noted by Perret (1973) the species displays sexual dimorphism, with the male having mottled flanks, unlike the prominent white lateral stripe of females. Gabon is the type locality for this forest species, which reaches a maximum SVL of 65 mm (Fuhn 1972). This species was transferred from the genus *Panaspis* to *Leptosiaphos* by Broadley (1989a) in an expanded subgenus *Lacertaspis*.

Suborder Serpentes
Family Atractaspididae: Subfamily Atractaspidinae: Genus *Atractaspis*

Four species of *Atractaspis* have been recorded from Gabon (Laurent 1950), only one of which was obtained during the survey.

Atractaspis corpulenta (Hallowell 1854)

PEM R 5257, 15689. Sites 5 and 10: The large (563 + 43 = 606 mm) female (PEM R 15689) was active in the early evening. The gut was empty and only small ova (<5 mm) were present. The male (PEM R 5257) was mature (425 + 38 mm), but the testes were inactive. The retracted hemipenis extended to the 7th subcaudal and was shallowly forked (dividing at 6th subcaudal). Ornamentation comprised seven rows of flounced spinose rows, the sulcus running centripetally to the fork between the shallow arms.

Family Boidae: Subfamily Erycinae: Genus *Calabaria*

Kluge (1993) demonstrated that the genus *Calabaria,* long considered a burrowing relative of pythons, shared numerous synapomorphies with erycine boids. The transfer of the only species to the Erycinae was well founded. However, his inclusion of the species with two New World erycines in the genus *Charina* remains more problematic and we choose not to follow it. Although taxonomically conservative, it obscures important differences between the Old and New World congeners, not least the differing reproductive modes.

Calabaria reinhardtii (Schlegel 1848)

PEM R 15708. Site 9: An adult female (782 + 65 mm) was found curled up in a hollow of a fallen tree.

Family Colubridae: Tribe Lamprophiini: Genus *Bothrophthalmus*

Bothrophthalmus lineatus (Peters 1863)

PEM R 5266. Site 10: A large female (746 + 176 mm). The stomach contained a large unidentified rodent. The specimen conforms to the *brunneus* phase, lacking the usual prominent body stripes; coloration is uniform brown with orange-red ventrum with dusky infusions on the subcaudals and lateral edges of the ventrals. Roux-Esteve (1965) noted that, apart from color, no other features distinguished *B. lineatus brunneus* Günther 1963 from typical *B. lineatus*, and considered the race invalid. However, only the *brunneus* phase has been recorded from Gabon and further studies of the situation are merited.

Tribe Lamprophiini: Genus *Mehelya*

In the last revision of the genus *Mehelya*, Loveridge (1939) recognized seven species including *M. poensis, M. capensis, M. crossii, M. nyassae, M. stenophthalmus, M. guirali*, and *M. riggenbachi*. Three additional species have been described subsequently: *M. vernayi* (Angola), *M. laurenti* (Congo and DCR) and *M. egbensis* (Nigeria). The two latter species remain poorly known, and no further specimens have been recorded since the type descriptions. The main distribution of the genus is around Cameroon (four species) and Nigeria (five species).

Mehelya capensis savorgnani (Mocquard 1887)

PEM R 5263. Site 10: A large male (850 + 151 mm). The stomach contained two undigested frogs (snout-burrowers, *Hemisus* cf. *perreti),* whilst the hindgut contained indeterminate mammal bones and hair. *Mehelya capensis* is traditionally considered to be a specialist ophiophage. However, Shine and colleagues (1995) reviewed dietary records for the genus and noted that *M. capensis* ate almost as many lizards as snakes, and that the few amphibian records were all bufonids. The lack of snake scutes associated with the mammal hair in the hindgut indicates that the above item was primary prey, and not secondarily ingested with snake prey. Hemisotids and mammals have not previously been recorded in the diet of this species.

Mehelya guirali (Mocquard 1887)

PEM R 15709. Site 5: A single female individual was collected (955 + 145 mm). The stomach contained a small bolus of snake scales. Loveridge (1939) recorded no specimens from Gabon. The only other record (MNHN 1896-540) for Gabon is a snake from Lambarene (Broadley *in litt.* November 2000).

Subfamily Incerta cedis: Genus *Grayia*

Grayia ornata (Bocage 1866)

PEM R 5255. Site 10: Only the head of an adult was preserved; 19 scale rows at neck, lower temporal equal in length to distance from loreal, and eight lower labials.

Subfamily Colubrinae: Genus *Boiga*

Chippaux (2001) placed African *Boiga* in the genus *Toxicodryas*, although this was not supported by Rasmussen's (1979) analysis of boigine snakes.

Boiga pulverulenta (Fischer 1856)

PEM R 15690. Site 6: A single female individual (SVL 867 mm, tail truncated) was collected. It was active in a tree about one hour after sunset. It approaches the maximum SVL recorded for the species (unsexed, 880 mm, Ghana; Pitman 1974). Like other specimens from Rabi (unpubl. observ.) it has 21 MSR (19 is typical for the species). This condition, previously unreported in the species (Rasmussen pers. comm., 23 May 2002), can cause confusion with *B. blandingii*. The two species are best distinguished by the vertebral scale row, which in *B. blandingii* is twice the width of the adjacent scales, but only slightly larger in *B. pulverulenta*.

Genus *Crotaphopeltis*

Crotaphopeltis hotamboeia (Laurenti 1768)

PEM R 5256, 15702–5. Sites 7 and 10: A relatively small female (361 mm SVL) contained six almost mature eggs (22–27 × 8–10 mm) when captured (date of collection unknown). Five snake eggs were found under a rock on 26 February 2000. These started hatching during the afternoon of 13 March and all individuals had emerged by the next morning. They measured 151–172 mm TL. Egg and hatchling size, as well as the small size of sexually mature snakes, correspond to previous records for southern African snakes (Keogh et al. 2000).

Genus *Dipsadoboa*

Rasmussen (1989) reviewed the *D. duchesnii* complex, restricting *D. duchesnii* to the Central African rain forests, being replaced to the west of the Dahomey Gap by *D. brevirostris*. He listed a number of specimens from Gabon.

Dipsadoboa duchesneii (Boulenger 1901)

PEM R 15724, 15801. Sites 3 and 9: Both individuals were sexually inactive females with empty guts. The largest measured 617 + 227 = 844 mm. The individuals were active at night during rain and were found in close proximity of calling *Hyperolius* species. The individual at site 3 was in reeds close to the water's surface with *H. guttulatus* calling within 50 cm. The individual at site 9 was 1.5 m up in a tree from which *H. ocellatus* were calling. The congener *D. aulica* has also been observed apparently stalking calling hyperoliids in Kwazulu-Natal, South Africa (Branch, unpub. observ.). Rasmussen (1989) recorded a maximum female total length of 990 mm; this was approached by another female (PEM R 15725) of 703 + 235 = 938 mm from Ekwata, Libreville.

Dipsadoboa weileri (Lindholm 1905)

PEM R 5264. Site 10: An adult male (525 + 116 mm). It conforms with Rasmussen's (1993) extended description of the species, with the exception that the loreal is fused with the preocular on one side. The stomach contained two undigested frogs (snout-burrowers, *Hemisus* cf. *perreti)*. The diet suggests that the species may be primarily terrestrial. In support of this supposition, the species also has a stouter build and shorter tail than its mainly arboreal congeners.

Genus *Hapsidophrys*

Broadley (1966) noted that the monotypic genera *Gastropyxis* and *Hapsidophrys* were both poorly differentiated, and formally synonymized the genera. Although this has not

been generally recognised (e.g., Pitman 1974; Rasmussen 1991; Meirte 1992; Akani et al. 1999), we support Broadley's transfer.

Hapsidophrys smaragdina (Schlegel 1837)
     PEM R 15710. Site 5: A single male (540 + 367 mm) was caught in a snap-trap set for small mammals.

Genus *Philothamnus*

Philothamnus carinatus (Andersson 1901)
     PEM R 5261–62. Site 10: Two adults, one of each sex. Both lack white spots, have vague dark crossbands on the forebody, and have 13 midbody scale rows. The simple hemipenis of the male extends to 6th–7th subcaudal. Ornamentation is typical for the genus, with two enlarged, ossified basal spines, followed distally by 8–10 crenelated spiny rows that reduce in size towards the tip where they are replaced by calyces. The sulcus is undivided and runs to the tip of the organ. Both guts were empty.
     Hughes (1985) discussed the difficulty of distinguishing this species from *P. heterodermus,* but validated its specific status (although not giving a full analysis of variation between the two taxa). Both Hughes (1985) and Chippaux (2001) mapped only 1–2 localities (unspecified) for the species in Gabon.

Philothamnus sp. 1
     PEM R 15802. Site 7: An advanced embryo was prematurely removed (6 May) from one of three eggs found under a log on 27 February. It is referable to *Philothamnus*, but insufficient detail on scalation and dentition were available for specific identification.

Genus *Rhamnophis*
     Broadley and Wallach (2003) have revised the Dispholidini, reviving the genus *Rhamnophis*.

Rhamnophis aethiopissa Günther 1862
     PEM R 5265. Site 10: A large male (884 + 504 mm). The stomach contained a *Leptopelis* sp.
Subfamily Natricinae: Genus *Natriciteres*

Natriciteres fuliginoides (Günther 1858)
     PEM R 5260, 15706. Sites 8 and 10: A single individual was collected in forest habitat during the surveying period and another subsequently by V. Nicolas. Loveridge (1958) recorded *Natriciteres fuliginoides* in Gabon from Franceville, Lambarene, and Ogooue River.

Family Elapidae: Subfamily Bungarinae: Genus *Dendroaspis*

Dendroaspis jamesonii (Traill 1843)
     Site 7: Brian Fisher observed two individuals whilst clearing a road during the two week reconnaissance period prior to the actual survey. He described these snakes to M. Burger who concluded that they were *D. jamesonii.*

Genus *Naja*

Naja melanoleuca (Hallowell 1857)

PEM R 5259. Sites 6 and 10: Voucher specimen is a large decapitated head with prominent black and white barred labials. Fragments of sloughed skin from a large (> 1.2 m) cobra, possibly of this species, were found at Camp 1.

Family Viperidae: Subfamily Causinae: Genus *Causus*

Causus lichtensteini (Jan 1859)

PEM R 5258. Site 10: A large male (361 + 42 mm) with dark coloration, with little indication of dark chevron pattern and lacking the white nape band of juveniles. The gut was empty. The retracted hemipenis extends to the 7th subcaudal, is strongly divided (at the 1st subcaudal), and has a very short nude basal region. Ornamentation comprises approximately seven rows of ossified spines on the proximal 80% of the arms and is calyculate for the remaining distal section.

Subfamily Viperinae: Genus *Atheris*

Atheris squamigera (Hallowell 1856)

PEM R 15695–96. Site 8: A large female (530 + 104 mm) was found about 2 m up a thin-stemmed tree. She contained 10 (8-2) large yolked eggs (10–17 × 14–15 mm); the stomach contained an unidentified mammal and the lower intestine was packed with mammal hair. A color photo of this specimen was published in Burger (2002a). A juvenile (193 + 39 mm) was found on the ground. It had typical, chocolate brown, juvenile coloration, with a light yellow tail tip.

The taxonomy of *A. squamigera* has been the subject of recent debate (Broadley 1998b; Lawson 1999; Lawson and Ustach 2000). Libreville is the type locality of *A. squamigera*, to which the Monts Doudou specimens remain referable.

Genus *Bitis*

Bitis gabonica (Duméril, Bibron and Duméril 1854)

PEM R 5252–54. Site 10: Three small specimens with prominent umbilical scars. A molecular phylogeny of *Bitis* (Lenk et al. 1999) indicated that the two races of *B. gabonica* are best treated as separate species, with western *B. rhinoceros* having closer affinities with *B. nasicornis,* and occurring west of the Dahomey Gap.

Order Crocodylia: Family Crocodylidae: Genus *Crocodylus*

All of the three African crocodile species occur in Gabon. We recorded *C. cataphractus* only, but according to Christian Nziengui (a WWF employee in the Gamba Region), *Osteolamus tetraspis* is known at Monts Doudou from small rivers and pools in forest habitat and the larger *Crocodylus niloticus* is known from the Mougalaba River.

Crocodylus cataphractus Cuvier 1825

Site 3: A single adult (approximate TL 1.5 m) was observed at close range at night. This individual was lying in a swamp with its head resting on the bank and about two-thirds of its body in the water.

Order Testudines: Family Pelomedusidae: Genus *Pelusios*

Iverson (1992) recorded four species of *Pelusios* (*P. carinatus, P. castaneus, P. gabonensis*, and *P. niger)* from Gabon. Bour (2000) has recently described another species, *P. marani*, from the country. We recorded only *Pelusios castaneus*, a common species occurring from northern Angola northwards in all west African countries up to Senegal.

Pelusios castaneus (Schweigger 1812)

PEM R 15687–88. Site 1: A few individuals were observed in small ponds at Doussala. Although no pelomedusids were observed in forest habitat at Monts Doudou, it is expected that some do occur.

Family Testudinidae: Genus *Kinixys*

Kinixys erosa (Schweigger 1812)

PEM R 15684–86. Sites 5, 8, and 9: This was the only reptile species captured by the pitfall traps. Three adults fell into the buckets on three different days at Camp 2 and a juvenile was also collected from this locality. Adult individuals were recorded from altitudes between 110 m and 640 m. *Kinixys erosa* is unusual in that individuals are mostly active at night (Schmidt 1919; Naulleau 1988) and they can swim and dive for food (Broadley 1989b). Gramentz (2001) noted that the species is threatened in Gabon by deforestation and exploitation for food.

DISCUSSION

The 263 amphibian captures over 726 pitfall trap-days (Table 3) translate to a daily capture rate of 36%, a figure which is very high when compared with 2% and 3% recorded for amphibians and reptiles in similar studies conducted in Madagascar (Raxworthy et al. 1998; Nussbaum et al. 1999). This excessive capture rate is primarily a product of high capture numbers of two species, i.e., *Xenopus epitropicalis* (138 specimens) and *Hemisus perreti* (53 specimens), together they account for 73% of the amphibian pitfall captures. Given that high numbers of a few species captured could so radically influence the daily capture rate, is this in fact an appropriate measure for trapping success and comparative survey assessments? We feel that, even though this measure is informative in respect to the extent of pitfall captures, it is not ideal for the type of comparisons that are important for evaluating trapping success. The terms "daily trap success" or "capture success" and "capture rate" have been used intermittently for the same measurement (e.g., Raxworthy and Nussbaum 1996; Raxworthy et al. 1998; Nussbaum et al. 1999; Goodman and Jenkins 1998; Goodman and Hutterer, this volume). We used "capture rate" over "capture success" in evaluating our pitfall results, but we propose that an alternative measure would better serve to assess capture or trapping success.

The calculation for daily capture success or capture rate (*op. cit.*) is the number of captures divided by the total trap-days. The inappropriateness of using this measure is illustrated by the fact that, according to the above definition, the daily capture rate of trap line 2 of Camp 1 was 108% (see Table 3). We propose that daily capture success should be the sum of the number of traps containing frogs divided by the number of trap-days calculated on a daily basis, divided by the number of days (survey period). In order to use this formula, the field data being recorded must note the daily results of individual pitfall traps and

not merely the combined daily results of each trap line. We did not do this ourselves unfortunately, and thus we could not apply this formula to the Monts Doudou results.

In terms of contributing to the overall herpetological species richness, the pitfall trapping efforts were of limited success. Seven amphibian species and one reptile, *Kinixys erosa*, were captured in pitfalls (Table 3). Of these, only *Hemisus perreti* was not recorded by means of opportunistic searches. The pitfalls were, however, efficient in terms of capturing good series of species that were otherwise rarely encountered opportunistically—more than 95% of *Xenopus epitropicalis* and about 90% of *Geotrypetes seraphini* specimens were from pitfall captures. We are puzzled by the paucity of reptile captures by these traps, particularly since the pitfall line set at the Université de Rennes Camp (site 5) collected four specimens comprising three skink species, i.e., *Mabuya affinis*, *M. polytropis*, and *Leptosiaphos breviceps*.

The species data obtained from localities other than the elevational transect (Camps 1, 2 and 3) account for 35.1% of the total herpetofaunal richness recorded during this survey (excluding the eight reptile species sampled afterwards). In comparison with the three camps, collecting effort at these sites was much less and thus we expect that the overall species richness figure for Monts Doudou would be increased substantially by increased survey efforts. Reptiles in particular were poorly represented in our survey (24 species and another eight subsequently) and we believe the real richness may be double that currently recorded. Using the combined results of all sampling techniques, the trend of the amphibian species accumulation curves (Fig. 1) suggest that continued effort at Camps 1 and 2 would probably have increased the species richness for these sites. The curve for Camp 3, however, flattened off comparatively sooner and an extended sampling effort here will presumably less likely to be met with a concurrent increase in species richness.

Reptile records obtained during this survey are insufficient for any meaningful analyses of site partitioning (see Table 5). Comparisons of amphibian species turnover between the three camps show only moderate evidence of elevational effects (see Table 4 and Fig. 2). Richness figures were similar with 21 species from Camp 1, and 22 and 17 species from Camps 2 and 3, respectively. Of the 34 combined species recorded, Camp 1 was most different with eight unique species (38.1% uniqueness), six species were particular to Camp 2 (27.3% uniqueness) and only two were particular to Camp 3 (11.8% uniqueness). Camps 1 and 2 combined had 94.1% (32 of 34) of the recorded species. Camps 2 and 3 combined accounts for 76.5% (26 of 34) of the species, thus further demonstrating the relatively greater uniqueness of Camp 1 in the overall comparisons of the three camps. The coefficients of community, or similarity indices, are presented in Table 6. The highest coefficient (0.50) is between Camps 2 and 3. The "capture rate" of amphibians decreased sharply from the lowest elevation up to the highest, with overall rates of 74.6%, 20.4% and 8.2% at camps 1, 2, and 3, respectively.

The above results do not attest to a mid-altitude "bulge" that has been reported for herpetofaunal diversity in Madagascar (Raxworthy et al. 1998; Nussbaum et al. 1999), but they do partially support the trend of a herpetofaunal diversity decline at higher elevations (Raxworthy and Nussbaum 1996; Nussbaum et al. 1999). It must be noted, however, that the Monts Doudou elevational gradient is quite different from the Madagascar studies. At the Réserve Naturelle Intégrale d'Andringitra the transect was over an altitude range of 1650 m (i.e., 650–2300 m), at the Anjanaharibe-Sud Massif the range was 1200 m (800–2000 m) and at the Réserve Naturelle Intégrale d'Andohahela it was 1435 m (440–1875 m). The Monts Doudou elevational transect was of a much shorter range (550 m) and it commenced and terminated at lower altitudes (110–660 m).

TABLE 5. Details of reptilian species turnover between Camps 1, 2, and 3. The first column lists the cumulative 16 species recorded from all three camps. The next three columns reflect species occurrence at these camps, followed by species uniqueness (U) at each camp and species shared (=) between camps. The last two columns show combined (+) species richness of Camps 1 and 2, and Camps 2 and 3 respectively. Note that Camp 1 consists of study sites 4, 6, and 7; Camp 2 is site 8 and Camp 3 is site 9.

Species - Reptilia	1	2	3	U1	U2	U3	1=2	1=3	2=3	1+2	2+3
Atheris squamigera		1			1					1	1
Boiga pulverulenta	1			1						1	
Calabaria reinhardtii			1			1					1
Crotaphopeltis hotamboeia	1			1						1	
Dipsadoboa duchesnii			1			1					1
Feylinia grandisquamis	1	1					1			1	1
Hemidactylus fasciatus	1	1	1					1	1	1	1
Hemidactylus muriceus	1			1						1	
Kinixys erosa		1	1						1	1	1
Leptosiaphos breviceps		1			1					1	1
Mabuya affinis	1			1						1	
Mabuya polytropis	1	1					1			1	1
Naja cf. melanoleuca	1			1						1	
Natriciteres fuliginoides		1			1					1	1
Philothamnus sp. 1	1			1						1	
Rampholeon spectrum		1	1						1	1	1
TOTALS	9	8	5	6	3	2	2	1	3	14	10

With the above in mind, an elevational analyses of herpetofaunal diversity at Monts Doudou should best be conducted following some further intensive surveys, since species turnover along such a short altitudinal range is likely to be less pronounced and would require a larger data set to be measured effectively. In a number of cases our data did show some strong evidence of species turnover, the best examples being 53 specimens of *Hemisus perreti* at Camp 1 and none further up; 120 specimens of *Xenopus epitropicalis* at Camp 1, 18 specimens at Camp 2 and none at Camp 3; 11 specimens of *Phrynobatrachus auritus* at site 5 and Camp 1, but none further up; about 15 observations of *Astylosternus batesi* at Camp 3 and none further down. However, there are also some instances that, at first glance, may be interpreted as a marked elevational partitioning when in fact this may not be the case. For example, four specimens of *Arthroleptis variabilis* were recorded from Camp 3 and none from the lower two camps. Yet a single specimen of this species was collected at site 5 which is located less than 1 km from Camp 1 at the same altitude. The main problem with our data set is that it includes numerous species for which only small numbers were collected or observed, e.g., *Trichobatrachus robustus* (1 specimen), *Alexteroon obstetricans* (1), *Xenopus fraseri* (1), *Bufo tuberosus* (2), *Nectophryne batesii* (2), *Leptopelis rufus* (2) and *Petropedetes* sp. 1 (3). The current faunal compositions of the various camps could easily have been very different were these species not recorded in a particular camp or if they were also recorded from further camps. Examples of species only re-

TABLE 6. Coefficients of community (C) (above diagonal) and number of species shared (below diagonal) between four of the localities sampled at Monts Doudou. C = number of shared species divided by the total number of species of the two localtlities being compared.

	Site 3	Camp 1	Camp 2	Camp 3
Site 3 (110 m)	–	0.03	0	0
Camp 1 (110 m)	1	–	0.34	0.36
Camp 2 (350–425 m)	0	11	–	0.50
Camp 3 (585–660 m)	0	10	13	–

corded at mid-altitude (Camp 2) should also be regarded as being non-conclusive (e.g., *Chiromantis rufescens* and *Scotobleps gabonicus*).

Apart from some of the elevational differences that we have highlighted, the current limited data set for Monts Doudou also shows evidence of greater variation between sites situated at the same altitude. The measures of uniqueness that we already presented above for Camps 1 to 3 were 38.1%, 27.3%, and 11.8%. If site 3 is compared with Camp 1, they have a very low similarity index of 0.03 (Table 6), and high uniqueness values of 92.3% and 95.2% respectively. These sites are about 7 km apart, both are in forest habitat, but the wetland types are very different—standing marshes at site 3 versus a flowing stream at Camp 1. Although sampling effort at site 3 was only about 12 hours during two nights, we did not lump the data from here with that of Camp 1 since this would have introduced a sampling bias and hindered comparisons between the three elevational camps. The main point to consider here is that only one of the 13 species recorded at site 3 was also recorded at Camp 1. Thus it seems likely that habitat heterogeneity within a particular altitude may in fact be more influential as a determinant of amphibian communities. Hofer and colleagues (2000) studied the effects of ecotones and elevational gradients (900–2000 m) on herpetological communities in the primary forest of Mount Kupe, Cameroon. They recorded significant relationships with the elevational gradient for both reptile and amphibian communities. However, frogs also showed a response to ecotones, especially in respect to presence or absence of watercourses.

Considering that 72 amphibian species are known from Gabon (Frétey and Blanc 2000), the current Monts Doudou total of 54 is a relatively high proportional richness for a single locality. In comparison for example, Frétey and Dewynter (1998) recorded 38 anuran species from the Forêt des Abeilles, Gabon, and Largen and Dowsett-Lemaire (1991) recorded 39 anurans from the Kouilou River Basin in the Congo. But we believe that these are still early days for herpetological assessments in Gabon. The two independent surveys conducted in Gabon during January to March 2000 pushed the country's total up to 84 species. The first study (Lötters et al. 2000; Lötters et al. 2001) discovered six species new for Gabon. Our study found two of those species and another six species new for Gabon and eleven unidentified species. The latter may include undescribed species, or recognized species new for Gabon, or species already known from Gabon. Thus it is not inconceivable that the real total for Gabon may in fact exceed 100 species. Future surveys of Monts Doudou amphibians are likely to add many more species to the current total of 54, particularly if a mixture of habitat types were to be surveyed. A case in point is the fact that the last four species added to the Monts Doudou total were recorded in savanna on the last night as the survey drew to an end.

The Monts Doudou material includes amphibian genera (*Hemisus* and *Kassina*) that are first-time records for Gabon. Likewise the genera *Hoplobatrachus* and *Trichobatrachus*

are also new for Gabon, having been recorded during our survey and also by Lötters et al. (2001). Amphibian genera known to occur in Gabon, but which were not recorded during our survey are *Aubria*, *Chlorolius*, *Cryptothylax*, *Herpele*, *Hymenochirus*, *Lepto-dactylodon*, and *Opisthothylax* (Frétey and Blanc 2000).

Although this survey has contributed substantially towards the herpetofaunal knowledge of Monts Doudou and Gabon in general, the results also clearly show that much more is still to be learned about the amphibians and reptiles of Gabon. The current impoverished knowledge is not only in terms of inadequacies in alpha-level taxonomy, species lists, and zoogeographic analyses, it is especially acute with respect to basic information regarding life history and ecology of the Gabonese herpetofauna. The opportunities and tasks ahead are ample and would require much greater effort than the once-off, rapid-assessment approach that we used. The only sure way in which to achieve this is by means of local expertise capacity building. Lawson and Klemens (2001) believe that the amphibian species richness disparity between comparable African and Neotropical countries is not necessarily because of a real higher faunal diversity of the latter. Instead they make a case that the higher diversity is correlated with increased research efforts which commenced in the 1960s. The development of national scientific capacity over the successive 40 years gave rise to an unprecedented increase in species descriptions of Colombian and Ecuadorian amphibians. They also make the point that the alpha-level taxonomy of African amphibians and reptiles is still rudimentary and thus there exists considerable scope for new species discoveries and descriptions if a generation of national biologists were to be trained. The current onslaught on the natural environment from timber exploitation, increased agriculture, and mining is starting to reach alarming proportions, thus making the development of relevant national expertise in central African countries a matter of extreme urgency.

LITERATURE CITED

AKANI, G. C., L. LUISELLI, AND E. POLITANO. 1999. Ecological and conservation considerations on the reptile fauna of the eastern Niger Delta (Nigeria). Herpetozoa 11(3/4):141–153.

AMIET, J.-L. 1972. Les *Cardioglossa* camerounaises. Sci. et Natur. 114:11–24.

———. 1977 "1978." Les *Astylosternus* du Cameroun (Amphibia, Anura, Astylosternidae). Ann. Fac. Sci. Yaoundé 23–24:99–227.

————. 1992 "1991." Un *Leptopelis* méconnu de la faune forestiêre camerounaise (Amphibia, Anura, Hyperoliidae). Alytes 9(4):89–102.

————. 2000. Les *Alexteroon* du Cameroun (Amphibia, Anura, Hyperoliidae). Alytes 17(3–4):125–164.

BAUER, A. M. AND O. S. G. PAUWELS. 2002. A new forest-dwelling *Hemidactylus* (Squamata: Gekkonidae) from Gabon, West Africa. African Journal of Herpetology 51:1–8.

BILLES, A. 2000. Mayumba, site d'importance internationale pour la ponte des tortues marines. Canopée 16:11–12.

BLANC, C. P. 1998. Mission ECOFAC GABON/AGRECO-GEIE. Reptiles et Amphibiens. Réserve de faune de Lopé (09 mars 1995–09 avril 1995). Rapport scientifique de mission. 29 pp.

BLANC, C. P. AND T. FRÉTEY. 2000a. Les Reptiles de la Réserve de faune de la Lopé et de la Forêt des Abeilles (Gabon). Bull. Soc. Zool. Fr. 125(4):281–292.

————. 2000b. Biogeographie des Amphibiens d'Afrique Centrale et d'Angola. Biogeographica 76(3):107–118.

BÖHME, W. 1975. Zur Herpetofaunistik Kameruns, mit Beschreibung eines neuen Scinciden. Bonn. zool. Beitr. 26:1–48.

————. 1988. Zur genitalmorphologie der Sauria: Funktionelle und stammesgeschichtliche aspekte. Bonn. zool. Monog. 27:1–176.

BOSCH, J., I. DE LA RIVA AND R. MÁRQUEZ. 2000. Advertisement calls of seven species of hyperoliid frogs from Equatorial Guinea. Amphibia-Reptilia 21:246–255.

BOULENGER, G. A. 1899. Descriptions of new Batrachians in the Collection of the British Museum (Natural History). Ann. Mag. Nat. Hist. 7(3):273–277.

————. 1900. A List of the Batrachians and Reptiles of the Gaboon (French Congo), with Descriptions of new Genera and species. Proc. Zool. Soc. (London) 1900:433–456, pl. XXVII–XXXII.

BOUR, R. 2000. Une nouvelle espéce de *Pelusios* du Gabon (Reptilia, Chelonii, Pelomedusidae) Manouria 3(8):1–32.

BROADLEY, D. G. 1966. A review of the Natal Green Snake, *Philothamnus natalensis* (A. Smith), with a description of a new subspecies. Ann. Natal Mus. 18(2):417–423.

————. 1989a. A reappraisal of the genus *Panaspis* Cope, with the description of a new species of *Leptosiaphos* (Reptilia: Scincidae) from Tanzania. Arnoldia Zimbabwe 9(32):439–449.

————. 1989b. *Kinixys erosa* Serrated Hinged Tortoise. Pp. 56–57 *in* The Conservation Biology of Tortoises. I. J. Swingland and M. W. Klemens, eds. Occasional Papers of the IUCN Species Survival Commission 5:1–202.

————. 1998a. The reptilian fauna of the Democratic Republic of the Congo. Pp. xvi–xviii *in* Contributions to the herpetology of the Belgian Congo, K. P. Scmidt and G. K. Noble. With introductions by D. G. Broadley and J. C. Poynton. SSAR Facsimilie Reprint, Ithaca.

————. 1998b. A review of the genus *Atheris* Cope (Serpentes: Viperidae), with the description of a new species from Uganda. Herpetol. J. 8:117–135.

————. 2000. A review of the genus *Mabuya* in southeastern Africa (Sauria: Scincidae). Afr. J. Herpetol. 49(2):87–110.

BROADLEY, D. G. AND V. WALLACH. 2003. In press. Review of the Dispholidini, with the description of a new genus and species from Tanzania (Serpentes: Colubridae). Bull. Nat. Hist Mus. Lond.

BRYGOO, E. R. AND C. A. DOMERGUE. 1971. Notes sur le *Brookesia* (Chamaeleonides) de Madagascar. Description d'une espéce nouvelle, *B. antoetrae* n. sp. et des hemipenis de *B. stumpffi* et *B. ebenaui*. Remarques sur la reparition de *B. sumpffi*. Bull. Mus. Nat. Hist. Nat. 42(2):830–838.

BRYGOO, E. R. AND R. ROUX-ESTEVE. 1983. *Feylinia*, genre de Lézards Africains de la famille des Scincidae, sous-famille des Feyliniinae. Bull. Mus. natn. Hist. nat. Paris 4e ser. 5 (A):307–341.

BURGER, M. 2002a. Rainforest revelations. Africa Geographic 10(6):68–75.

————. 2002b. Frogs logged in Gabon. Eye Spied. Travel Africa 19:98.

CANNATELLA, D. C. AND L. TRUEB. 1988. Evolution of pipoid frogs: intergeneric relationships of the aquatic frog family Pipidae (Anura). Zool. J. Linn. Soc. 94:1–38.

CHANNING, A., D. MOYER, AND M. BURGER. 2002. Cryptic species of sharp-nosed reed frogs in the *Hyperolius nasuts* complex: advertisement call differences. African Zoology 37(1):91–99.

CHIPPAUX, J.-P. 2001. Les Serpentes d'Afrique occidentale et centrale. Faune et Flore Tropicales 35, Éditions de l'IRD, 292 pp.

COMBES, C. AND L.-P. KNOEPFFLER. 1967. Parasites d'amphibiens du Gabon Haematoloechidae (Digenea). Biol. Gabon 3:141–145.

DE LA RIVA, I., J. BOSCH, AND MÁRQUEZ, R. 2001. Calls of three species of arthroleptid frog from Rio Muni, Equatorial Guinea. Afr. Zool. 36(1):107–110.

DREWES, R. C. AND J. L. PERRET. 2000. A new species of giant, montane *Phrynobatrachus* (Anura: Ranidae) from the central mountains of Kenya. Proceedings of the California Academy of Sciences 55(5):55–64.

DUBOIS, A. 1992. Notes sur la classification des Ranidae (Amphibiens Anoures). Bull. Mens. Soc. Linn. Lyon. 61:305–352.

DUMÉRIL, A. 1856. Note sur les Reptiles du Gabon. Rev. Mag. Zool. Pure appl., Paris (2)8:369–377, 417–424, 460–470, 553–562, pl. 20–21.

DUNGER, G. T. 1968. The Lizards and Snakes of Nigeria. 4. The geckos of Nigeria. Nigerian Field 33:18–47.

DUPOUY, J. AND L.-P. KNOEPFFLER. 1978. *Polystoma chiromantis* n. sp. (Monogenea) chez *Chiromantis rufescens* (Günther, 1868) du Cameroun, du Gabon et de Centralafrique. Bull. Mus. natn. Hist. nat. Paris, Zool 353:217–220.

EUZET, L., C. COMBES AND L.-P. KNOEPFFLER. 1966. Parasites d'amphibiens du Gabon: Polystomatidae (Monogenea). Biol. Gabon 2:215–233.

FRETEY, J. 1998. Sites de ponte et menaces en Afrique de l'Ouest. La Tortue 43:4–7.

FRÉTEY, T. AND C. P. BLANC. 2000. Les Amphibiens d'Afrique centrale. Liste faunistique. ADIE. Libreville. Gabon. 40 pp.

———. 2001. Inventaire systématique des amphibians anoures du centre du Gabon. Bull. Soc. Zool. Fr. 126(4):375–390.

FRÉTEY, T. AND M. DEWYNTER. 1998. Amphibiens anoures de la Forêt des Abeilles (Gabon). J. Afric. Zool. 112(3):171–184.

FROST, D. R. 2000. Amphibian Species of the World: An online reference. V2.20 (1 September 2000). [http://research.amnh.org/herpetology/amphibia/index.html]

FUHN, I. E. 1972. Révision du phylum forestier du genre *Panaspis* Cope (Reptilia, Scincidae, Lygosominae). Rev. Roum. Biol. Zool. 17(4):257–271.

FUHN, I. E. AND D. JENKINS. 1998. The Insectivores of the Réserve Spéciale d' Anjanaharibe-Sud, Madagascar. Pp. 139–161 *in* A Floral and Faunal Inventory of the Réserve Spéciale d' Anjanaharibe-Sud, Madagascar: With Reference to Elevational Variation, S. M. Goodman, ed. Fieldiana: Zoology, n.s. 90:1–246.

GOSSMANN, V., S. LÖTTERS, F. OBAME, AND W. BÖHME. 2002. Zur Herpetofauna Gabuns. Teil II: Kommentiere Artenliste der gefundenen Reptilien, Bemerkungen zur Artenvielfalt. Herpetofauna 24(136):19–33.

GRAMENTZ, D. 1998a. Zur Morphologie und Merkm alsvariation von *Cycloderma aubryi* (Duméril, 1856). Salamandra 34(4):333–348.

———. 1998b. Zur Prädation und Antiprädationstrategie von *Cycloderma aubryi* (Duméril, 1856). Salamandra 34(4):349–358.

———. 1999a. Schwere Zeiten für Reptilien in Gabun. Elaphe 7(2):57–61.

———. 1999b. Zur ökologie und zum verhalten von *Pelusios casteneus* (Schweigger, 1812) und *Pelusios niger* (Duméril and Bibron, 1835) in Gabun. Sauria 21(3):7–14.

———. 1999c. Zur ökologie und ethologie von *Agama agama* (Linnaeus, 1758) in Lambaréné, Gabun. Salamandra 35(4):193–208.

———. 2001. Zur ökologie und ethologie von *Kinixys erosa* (Schweigger, 1812) in Gabun. Sauria 23(2):17–23.

GREER, A. 1970. A subfamilial classification of scincid lizards. Bull. Mus.Comp. Zool. Harvard 139:151–184.

GÜNTHER, A. 1896. Report on a Collection of Reptiles and Fishes made by Miss M. H. Kingsley during her Travels on the Ogowe River and in Old Calabar. Ann. Mag. Nat. Hist., sér 6E. 17:261–285, pl. XIII–XV.

HALLOWELL, E. 1857. Notice of a collection of Reptiles from the Gaboon country, West Africa, recently presented to the Academy of Natural Sciences of Philadelphia, by Dr. Henry A. Ford. Proc. Acad. Nat. Sci. Philadelphia 9:48–72.

HERRMAN, H.-W., W. BÖHME, AND P. HERRMAN. 2000. The Alsco Cameroon Herpetological Expedition 1988: The sampling of a mountain rainforest. Pp. 95–103 *in* Isolated Vertebrate Communities in the Tropics, G. Rheinwald ed. Bonn. Zool. Monog. 46.

HOFER, U., L.-F. BERSIER, AND D. BORCARD. 2000. Ecotones and gradients as determinants of herpetofaunal community structure in the primary forest of Mount Kupe, Cameroon. J. Trop. Ecol. 16:517–533.

HOOGMOED, M. S. 1974. Ghanese lizards of the genus *Mabuya* (Scinicidae, Sauria, Reptilia). Zool.Verhand. 138:1–62.

HUGHES, B. 1985. Progress on a taxonomic revision of the African tree snakes (*Philothmanus* spp.). Pp. 511–530 *in*: Proc. Int. Symp. African Vertbrates: Systematics, Phylogeny and Evolutionary Ecology, K. Schuchmann, ed. Zool. Forschung. Mus. A. Koenig, Bonn.

IVERSON, J. B. 1992. A Revised Checklist with Distribution Maps of the Turtles of the World. Privately Printed, Richmond, Indiana. 363 pp.

KEOGH, J. S., W. R. BRANCH, AND R. SHINE. 2000. Feeding ecology, reproduction and sexual dimorphism in the colubrid snake *Crotaphopeltis hotamboeia* in southern Africa. Afr. J. Herpetol. 49(2):129–137.

KLAVER, C. AND W. BÖHME. 1986. Phylogeny and classification of the Chamaeleonidae (Sauria) with special reference to hemipenis morphology. Bonn. Zool. Monog. 22:1–64.

KLUGE, A. G. 1993. *Aspidites* and the phylogeny of pythonine snakes. Rec. Austr. Mus. Suppl. 19:1–77.

KNOEPFFLER, L.-P. 1965. Le comportement fouisseur de *Conraua crassipes* (Amphibien anoure) et son mode de chasse. Biologica Gabonica 1(3):239–245.

———. 1966a. Faune du Gabon (Amphibiens et Reptiles) I. Ophidiens de l'Ogooué-Ivindo et du Woleu N'tem. Biologica Gabonica 2:1–23.

———. 1966b. *Cryptohylax greshoffi* (Amphibia Salientia, Rhacophoridae). Premières observations biologiques. Biologica Gabonica 2:157–161.

———. 1967a. Redecouverte de *Chamaeleo chapini* (De Witte). Biologica Gabonica 3:247.

———. 1967b. *Bufo petiti* n. sp. crapaud nain de la forêt gabonaise. Biologica Gabonica 3:249–252.

———. 1967c. Description du tédard de *Bufo camerunensis camerunensis* (Parker, 1936). Biologica Gabonica 3:403–406.

———. 1967d. *Xenopus fraseri* × *Xenopus tropicalis*, hybride naturel d'amphibiens anoures au Gabon. C. R. Acad. Sci., Paris 265:1391–1393.

———. 1968. Clef de détermination des serpents actuellement connus du Gabon et des contrées limitrophes (Moyen-Congo, Rio Muni, Cabinda et Sud Cameroun forestier). Biologica Gabonica 4:183–194.

———. 1974. Fauna du Gabon (Amphibiens et Reptiles) II.— Crocodiles, Cheloniens et Sauriens de l'Ogooue-Ivindo et du Woleu N'tem. Vie et Milieu 24(1) sér. C:111–128.

———. 1976. Food habits of *Aubria subsigillata* in Gaboon (Anura: Ranidae). Zoologica Africana 11(2):369–371.

———. 1979. Amphibien aus Gabun. Deutsche Gesellschaft Herpetol. Terrar. 61:7–8.

KOBEL, H. R., C. LOUMONT, AND R. C. TINSLEY. 1996. The extant species. Pp. 9–33 *in* The biology of *Xenopus*, R. C. Tinsley and H. R. Kobel, eds. Symposia of the Zoological Society of London, 68:1–440.

KLUGE, A. G. 1993. *Calabaria* and the phylogeny of erycine snakes. Zool. J. Linn. Soc. 107:293–351.

LAMOTTE, M. 1967. Les batraciens de la région de Gpakobo (Côte d'Ivoire). Bull. Inst. fon. Afr. Noire, sér A, 29:218–294.

LAMOTTE, M. AND J.-L. PERRET. 1968. Revision du genere *Conraua* Nieden. Bull. I.F.A.N., sér A, 30(4):1603–1644.

LANG, M. 1991. Generic relationships within Cordyliformes (Reptilia: Squamata). Bull. Inst. Roy. Sci. Nat. Belg. 61:121–188.

LARGEN, M. J. 1991. Lizards, turtles and tortoises (Reptilia: Sauria and Cryptodira) from the Kouilou River basin, République du Congo. Pp. 169–173 *in* Flore et faune du bassin du Kouilou (Congo) et leur exploitation), R. J. Dowsett and F. Dowsett-Lemaire, eds. Tauraco Research Report No. 4, Tauraco Press.

LARGEN, M. J. AND R. F. DOWSETT-LEMAIRE. 1991. Amphibians (Anura) from the Kouilou River basin, République du Congo. Pp. 145–168 *in* Flore et faune du bassin du Kouilou (Congo) et leur exploitation), R. J. Dowsett and F. Dowsett-Lemaire, eds. Tauraco Research Report No. 4, Tauraco Press.

LAURENT, R. 1950. Revision du genre *Atractaspis* A. Smith. Mem. Inst. Roy. Sci, Nat. Belg. 2nd series 38:1–49.

———. 1972. Tentative revision of the genus *Hemisus* Günther. Ann. Mus. R. Afr. Cent. Tervuren. sér 8, Sci. Zool. 194:1–67.

LAWSON, D. P. 1993. The reptiles and amphibians of the Korup National Park Project, Cameroon. Herpetological Natural History 1(2):27–90.

———. 1999. A new species of arboreal viper (Serpentes: Viperidae: *Atheris*) from Cameroon. Por. Biol. Soc. Wash. 112(4):793–803.

LAWSON, D. P. AND M. W. KLEMENS. 2001. Herpetofauna of the African Rain Forest: Overview and Recommendations for Conservation. Pp. 291–307 in African Rainforest Ecology and Conservation. W. Weber, L. J. T. White, A. Vedder and L. Naughton-Treves, eds. Yale University Press.

LAWSON, D. P. AND P. C. USTACH. 2000. A redescription of Atheris squamigera (Serpentes: Viperidae) with comments on the validity of Atheris ansiolepis. J. Herpetol. 34(3):386–389.

LENK, P., H.-W. HERRMANN, U. JOGER, AND M. WINK. 1999. Phylogeny and taxonomic subdivision of Bitis (Serpentes: Viperidae) based on molecular evidence. In Systematics, Phylogeny and Biology of the Viperidae, U. Joger and G. Nilson, eds. Kaupia 8:31–38.

LÖTTERS, S., V. GOSSMANN, AND F. OBAME. 2000. Erfassung der Divarsität der Amphibien und Reptilien Gabuns. Elaphe 8(3):63–66.

LÖTTERS, S., V. GOSSMANN, F. OBAME AND W. BÖHME. 2001. Zur Herpetofauna Gabuns. Teil I: Einleitung, Untersuchungsgebiet und Methodik, Kommentiere Artenliste der gefunden Froschlurche. Herpetofauna 23(133):19–34.

LOVERIDGE, A. 1939. Revision of the African snakes of the genera Mehelya and Gonionotophis. Bull. Mus. Comp. Zool. Harvard. 86(3):131–162.

———. 1947. Revision of the African Lizards of the Family Gekkonidae. Bull. Mus. Compar. Zool. Cambridge 98(1):1–469, pls 7.

———. 1958. Revision of Five African Snake Genera. Bull. Mus. Compar. Zool. Cambridge 119(1):1–198.

MAEDER, A.-M., C. COMBES, AND L.-P. KNOEPFFLER. 1969. Parasites d'amphibiens du Gabon: Plagiorchiidae et Paramphistomatidae (Digenea). Biol. Gabon 3:288.

MALEY, J. 1991. The African rain forest vegetation and palaeoenvironments during late Quaternary. Climatic Change 19:79–98.

MÁRQUEZ, R., I. DE LA RIVA AND J. BOSCH. 2000. Advertisement calls of Bufo camerunensis, Chiromantis rufescens, Dimorphognathus africanus and Phrynobatrachus auritus, from Equatorial Guinea (central Africa). Herpetological Journal 10:41–44.

MEIRTE, D. 1992. Cles de determination des serpents d'Afrique. Ann. Mus. Roy. Afr. Cent. Tervuren. Zool. 267:1–152.

MOCQUARD, M. F. 1897a. Note préliminaire sur une collection de Reptiles recueillie par M. Hang, á Lambaréné. Bull. Mus. natn. Hist. Nat. 3:54–55.

———. 1897b. Sur une collection de Reptiles recueillie par M. Hang, á Lambaréné. Bull. Mus. Soc. Philomath. Paris 8(9):5–20.

———. 1902. Sur des Reptiles et Batraciens de l'Afrique orientale anglaise, du Gabon et de la Guinée française (région de Kouroussa). Bulletin du Muséum d'Histoire Naturelle 8:404–417.

NAULLEAU, G. 1988. Activité déplacements de la tortue Kinixys erosa en forêt équatoriale Gabonaise. Mésogée 48:67–70.

NUSSBAUM, R. A., C. J. RAXWORTHY, A. P. RASELIMANANA AND J.-B. RAMANAMANJATO. 1999. Amphibians and Reptiles of the Réserve Naturelle Intégrale d'Andohahela, Madagascar. Pp. 155–173 in A Floral and Faunal Inventory of the Réserve Naturelle Intégrale d'Andohahela, Madagascar: With Reference to Elevational Variation, S. M. Goodman, ed. Fieldiana: Zoology, n.s. 94:1–297.

ODIERNA, G., A. CANAPA, F. ANDREONE, G. APREA, M. BARUCCA, T. CAPRIGLIONE, AND E. OLMO. 2002. A phylogenetic analysis of Cordyliformes (Reptilia: Squamata): Comparison of molecular and karyological data. Mol. Phylo. Evol. 23(1):37–42.

OHLER, A. 1996. Systematics, morphometrics and biogeography of the genus Aubria (Ranidae, Pyxicephalinae). Alytes 13(4):141–166.

———. 1999. Une nouvelle espèce du genre Leptodactylodon (Arthroleptidae, Astylosterninae) du Gabon. Alytes 17(1–2):73–80.

OHLER, A., AND M. KAZADI. 1990. Description d'une nouvelle espéce du genre Aubria Boulenger, 1917 (Amphibiens, Anoures) et redescription du type d' Aubria subsigillata (A. Duméril, 1856). Alytes 8(2):25–40.

PAUWELS, O. S. G., A. KAMDEM TOHAM, AND C. CHIMSUNCHART. 2002a. Recherches sur l'herpétofaune des Monts de Cristal, Gabon. Bulletin de l'Institut Royal des Sciences naturelles de Belgique, Biologie 72:59–66.

———. 2002b. Recherches sur l'herpétofaune du Massif du Chaillu, Gabon. Bulletin de l'Institut Royal des Sciences naturelles de Belgique, Biologie 72:47–57.

PERRET, J.-L. 1966. Les Amphibiens du Cameroun. Zool. Jahr., Abt. Syst. 8:289–464.

———. 1973. Contribution à l'etude des Panaspis (Reptilia, Scincidae) d'Afrique occidentale avec la description de deux espèces nouvelle. Rev. Suisse Zool. 80(2):595–630.

————. 1977. Les *Hylarana* (Amphibiens, Ranidés) du Cameroun. Revue suisse Zoologie 84(4):841–868.

————. 1984. Identification des syntypes de *Petropedetes obscurus* Ahl, 1924 (Amphibia, Phrynobatrachinae), conservés au muséum de Berlin. Bull. Soc. Neuch'tel. Sci. Nat. 110; 63–70.

PERRET, J.-L. AND J.-L. AMIET. 1971. Remarques sur les *Bufo* (Amphibiens Anoures) du Cameroun. Ann. De la Fac. Des Sciences du Cameroun 1971(5):47–55.

PITMAN, C. R. S. 1974. A Guide to the Snakes of Uganda, rev. ed. Wheldon and Wesley, Codicote. 290 pp.

POYNTON, J. C. 1996. Diversity and conservation of African bufonids (Anura): Some preliminary findings. Afr. J. Herpetol. 45(1):1–7.

————. 1999. Distribution of Amphibians in sub-Saharan Africa, Madagascar and Seychelles. Pp. 483–539 *in* Patterns of Distribution of Amphibians, W. D. Duellman, ed. John Hopkins University Press, Baltimore.

RASMUSSEN, J. B., 1979. An intrageneric analysis of some boigine snakes—Bogert's (1940) Group xiii and xiv (Boiginae, Serpentes). Viden. Med. Dansk Natur. Foren. 141:97–155.

————. 1989. A taxonomic review of the *Dipsadoboa duchesnei* complex. Bonn. Zool. Beitr. 40:249–264.

————. 1991. Snakes (Reptilia: Serpentes) from the Kouilou River basin, including a tentative key to the snakes of République du Congo. Pp. 175–188 *in* Flore et faune du bassin du Kouilou (Congo) et leur exploitation, R. J. Dowsett and F. Dowsett-Lemaire, eds. Tauraco Research Report No. 4, Tauraco Press.

————. 1993. A taxonomic review of the *Dipsadoboa unicolor* complex, including a phylogenetic analysis of the genus (Serpentes, Dipsadidae, Boiginae). Steenstrupia 19(4):129–196.

RAXWORTHY, C. J. AND R. A. NUSSBAUM. 1996. Amphibians and Reptiles of the Réserve Naturelle Intégrale d'Andringitra, Madagascar: A Study of Elevational Distribution and Local Endemicity. Pp. 158–170 *in* A Floral and Faunal Inventory of the Eastern Slopes of the Réserve Naturelle Intégrale d'Andringitra, Madagascar: With Reference to Elevational Variation, S. M. Goodman, ed. Fieldiana: Zoology, n.s. 85:1–318.

RAXWORTHY, C. J., F. ANDREONE, R. A. NUSSBAUM, N. RABIBISOA, AND H. RANDRIAMAHAZO. 1998. Amphibians and Reptiles of the Anjanaharibe-Sud Massif, Madagascar: Elevational Distribution and Regional Endemicity. Pp. 79–92 *in* A Floral and Faunal Inventory of the Réserve Spéciale d' Anjanaharibe-Sud, Madagascar: With Reference to Elevational Variation, S. M. Goodman, ed. Fieldiana: Zoology, n.s. 90:1–246.

RÖDEL, M.-O. 2000. Herpetofauna of West Africa. Vol. 1. Amphibians of the West African Savanna. Edition Chimaira, Frankfurt am Main. 332 pp.

ROUX-ESTÈVE, R. 1965. Les serpents de La Maboké-Boukoko. Cahiers de La Maboké 3(1):51–92.

SCHIØTZ, A. 1964. The voices of some West African Amphibians. Vidensk. Meddr. Dansk Foren. 127:35–83.

————. 1967. The treefrogs (Rhacophoridae) of West Africa. Spolia zool. Mus. Haun. 25:1–346.

————. 1999. Treefrogs of Africa. Edition Chimaira, Frankfurt am Main. 350 pp.

SCHMIDT, K. P. 1919. Contributions to the herpetology of the Belgian Congo based on the collection of the American Museum Congo Expedition 1901–1915. Part 1. Turtles, crocodiles, lizards and chameleons. Bull. Amer. Mus. Nat. Hist. 39:385–624.

SHINE, R., W. R. BRANCH, P. S. HARLOW AND J. K. WEBB 1995. Sexual dimorphism, reproductive biology and food habits of two species of African filesnakes (*Mehelya*, Colubridae). J. Zool (Lond.) 240:327–340.

TANDY, M. AND R. C. DREWES. 1985. Mating calls of the "kassinoid" genera *Kassina*, *Kassinula*, *Phlyctimantis* and *Tornierella* (Anura: Hyperoliidae). South African Journal of Science 81:191–195.

TILBURY, C. R. AND D. EMMRICH. 1996. A new dwarf forest chameleon (Squamata: *Rhampholeon* Günther 1874) from Tanzania, East Africa, with notes on its infrageneric and zoogeographic relationships. Trop. Zool. 9:61–71.

TOFT, C. A. 1982. Community structure of litter Anurans in a tropical forest, Makokou, Gabon: A preliminary analysis in the minor dry season. Rev. Ecol. (Terre Vie) 36:223–232.

TYS VAN DEN AUDENAERDE, D. F. E. 1967. Les Gekkonidae de l'Afrique centrale. Rev Zool. Bot. Afr. 76(1–2):163–172.

VERHEYEN, R. 1960. Note on the altitudinal range of the amphibians collected in the National Upemba-Park (Belgian Congo). Rev. Zool. Bot. Afr. 61:82–86.

WAARDENBURG, H. W. AND R. GUICHERIT. 1991. Reptiles and amphibians in the Ofoubou concession area, Gabon. Rapport Africa Forest/CONOCO Ndombo Ltd :1–13.

WILD, C. 1994. Ecology of the Western Pygmy Chameleon *Rhampholeon spectrum* Buchholz 1874 (Sauria: Chamaeleonidae). British Herpetological Society Bulletin 49:29–35.

Ichneumonid (Hymenoptera: Ichneumonoidea) Diversity Across an Elevational Gradient on Monts Doudou in Southwestern Gabon

Simon van Noort

Natural History Division, South African Museum (Iziko Museums of Cape Town),
P.O. Box 61, Cape Town, 8000, South Africa;
e-mail: svannoort@iziko.org.za

An analysis of the ichneumonid wasps collected during a four-week, diversity survey of Monts Doudou in southwestern Gabon revealed 112 species represented by 233 individuals. Ichneumonidae of Gabon are extremely poorly known, with 25 species in 14 genera currently recorded. This survey added a further 45 genera to the checklist of that country. The smoothed, species-accumulation curve showed no sign of reaching an asymptote, indicating that the ichneumonids were under-sampled. Abundance-based and incidence-based coverage estimators extrapolated estimated species richness to 305 and 312 species respectively, i.e., only 36–37% of the ichneumonid species estimated to be present were actually sampled. Ichneumonid species richness was similar across elevation with a 6% total variation between the 3 sampled altitudes. Species richness and abundance was highest at mid-elevation (350 m), followed by high elevation (630 m) and lastly low elevation (110 m). Species turnover was high between elevations, with 82% of the sampled species being unique to an elevation. Only 6% of the sampled species were shared across all three elevations and between 1.8% and 6% of total species richness shared between any two elevations. The Morisita-Horn index of similarity depicted that low and high elevation was more similar than mid-and high elevation or low and mid-elevation. Of the four methods deployed to collect ichneumonid wasps, sweeping was the most efficient in terms of procured species richness, followed by Malaise trapping; yellow pan trapping was inefficient, and was superseded by hand collecting. In terms of species return per individuals captured, all four methods were similarly efficient. Species complementarity between different methods was low. Malaise trapping and sweeping had the highest species overlap, although this was only 11% of the total sampled species richness and hence none of the sampling methods were redundant.

RÉSUMÉ

Une analyse des Ichneumons collectés pendant une période de 4 semaines au Mont Doudou a révélé 112 espèces représentées par 233 individus.

Les Ichneumonides de Gabon sont extrêmement mal connus avec, au jour d'aujourd'hui et avant cette étude, 25 espèces inclues dans 14 genres. Le présent inventaire a ajouté 45 autres genres à la liste des Ichneumonides du pays. La courbe d'accumulation régularisée d'espèces, qui n'atteint aucune asymptote, montre que les Ichneumonides sont encore insuffisamment inventoriés. Les estimateurs de richesse d'espèces basées sur l'abondance (ACE) et l'incidence (ICE) ont respectivement estimé le nombre d'espèces extrapolées à 305 et 312 et montre ainsi que seulement 36–37% des espèces supposées être présentes ont réellement été récoltées. La richesse en espèces d'Ichneumons était similaire

le long du gradient avec seulement une variation totale de 6% entre les trois altitudes échantillonnées. Le site à mi-élévation (350 m) est le plus riche en espèces et en spécimens, suivi par celui à haute élévation (630 m) et finalement par celui à basse altitude (110 m). La succession d'espèces est élevée entre différentes élévations avec 82% des espèces collectées sur une élévation étant uniques à cette élévation. Seulement 6% des espèces peuvent être trouvées sur les trois élévations et entre 1.8% à 6% peuvent être partagées par n'importe quel des deux sites choisis. L'index de similarité Morisita-Horn a présenté que les sites à basse et haute altitudes sont plus similaires entre eux que les sites à haute et mi-élévation ou les sites à basse et mi-élévation. Sur les quatre méthodes déployées pour récolter les ichneumons, le filet fauchoir est le plus effectif en termes de richesse en espèces, suivi par le piège malaise. Le piège bac est inefficace et est supplanté par la récolte manuelle. En termes de nombre d'espèces accumulées par individus capturés, les quatre méthodes sont aussi efficaces les unes que les autres.

La complémentarité d'espèces entre les différentes méthodes est faible. Même si le piège malaise et le filet fauchoir ont le plus d'espèces similaires capturées, ceci ne représente que 11% des totaux, montrant ainsi qu'aucune des méthodes n'est superflue.

INTRODUCTION

The order Hymenoptera is second only to the Coleoptera and Lepidoptera, in terms of number of described species (Arnett 1985). There are an estimated 115,000 described species of Hymenoptera (Gaston 1993; Grissell 1999; LaSalle and Gauld 1993), while the number of described species of Coleoptera ranges from 290,000 (Wilson 1992) to 400,000 (Hammond 1992), and that of Lepidoptera from 112,000 (Wilson 1992) to 150,000 (Hammond 1992). The current lower species richness of the Hymenoptera may be a function of unequal taxonomic attention, since investigations of local species richness have shown that the Hymenoptera are the most species rich of the insect orders in both temperate and tropical areas (Gaston 1991; Stork 1991). The estimated richness of extant Hymenoptera ranges between 300,000 and 2.5 million species (Grissell 1999). Whichever figure is more accurate it is clear that the Hymenoptera are taxonomically poorly known at species level. This predicament is slowly being addressed through rigorous quantified inventory surveys such as the Sulawesi Indonesia "Project Wallace" (Noyes 1989a; 1989b) and the INBio program in Costa Rica (Gauld 1991; Hanson and Gauld 1995; Gaston et al. 1996). Recently a number of structured hymenopteran inventories have been conducted in Tanzania, Namibia and South Africa. As part of an ecological inventory survey of Mkomazi Game Reserve in northeastern Tanzania (Coe et al. 1999), an assessment of hymenopteran species richness of this semi-arid east African savanna region was carried out (Robertson 1999; van Noort and Compton 1999; van Noort in prep.). An elevational assessment of hymenopteran species richness was assessed on the Brandberg Massif in Namibia (van Noort et al. 2000), and a comparative assessment of formicid and ichneumonid species richness between Afromontane forest and the adjoining upland grassland was conducted in Kwazulu-Natal in South Africa (Fisher and van Noort, in prep.). These studies, together with the current inventory survey of Monts Doudou, form part of a program of rigorously quantified inventory surveys targeting Afrotropical Hymenoptera, thereby allowing for repeatable and comparative assessments of species richness (Longino and Colwell 1997).

The Ichneumonidae are one of the most species-rich families of all organisms with an estimated 60,000 species in the world (Townes, 1969). According to Gauld (1991) many

authorities regard this figure as an underestimate. An estimated 12,100 species of Ichneumonidae occur in the Afrotropical region, of which only 1,815 had been described by 1973 (Townes and Townes 1973). Subsequently the single major revision of Afrotropical ichneumonids added a further 70 species of Ophioninae (Gauld and Mitchell 1978), with the result that only an estimated 15% of the Afrotropical ichneumonids are known to science. The ichneumonid fauna of Gabon is extremely poorly known, with a paltry 25 species in 14 genera having been recorded from the country (Yu 1998). Quantitative studies of ichneumonid species richness are scarce in Africa. The limited number of assessments have been conducted in Sierra Leone and Uganda (Owen and Owen 1974); Namibia (van Noort et al. 2000); Tanzania (van Noort in prep.) and South Africa (van Noort and Fisher, in prep.). The Ichneumonidae, along with other groups of parasitic Hymenoptera, are purported to be no more species rich in the tropics than in the Northern Hemisphere temperate regions (Owen and Owen 1974; Janzen 1981; Janzen and Pond 1975), although a number of hymenopteran families, for example the Chalcididae (Hespenheide 1979) and Encyrtidae (Noyes 1989b) exhibit an increase in species richness with a decrease in latitude. Other hymenopteran taxa such as sawflies (Symphyta), gall-forming Cynipidae, and bees (Apoidea) peak in species richness at mid- or high latitudes (Michener 1979; Noyes 1989b; Kouki et al. 1994). Considerable debate has centered on the apparent species richness anomaly exhibited by a number of hymenopteran parasitoid taxa in the tropics (e.g., Morrison et al. 1978; Gauld 1991; Gauld and Gaston 1994).

The family Ichneumonidae is currently split into 37 subfamilies, of which 24 have been recorded from the Afrotropical region (Yu 1998). Ichneumonids utilise a diverse array of insects and arachnids as their hosts and play an essential role in the normal functioning of most ecosystems, underlining the need to inventory their diversity. Comprehensive, quantitative, biodiversity surveys will enable the identification of hotspots of species richness and endemism. This essential base line data will enable informed conservation management decisions.

In this paper a baseline inventory assessment of ichneumonid species richness and diversity on Monts Doudou is provided and placed in the context of contemporary knowledge of world ichneumonid species richness. Patterns of species richness across an elevational gradient of 550 m, from the base to the peak of Monts Doudou, are assessed. The known biogeographical affinities and biology of the sampled genera are reported.

MATERIALS AND METHODS

Study site

Three localities representing different elevations were sampled on Monts Doudou, which is situated in Province Ogoové-Maritime in southwestern Gabon. The first locality was situated in the Réserve de la Moukalaba-Dougoua at an elevation of 110 m, 12.2 km 305° NW Doussala, 2°17.00'S, 10°29.83'E. The second and third localities were situated in the Réserve des Monts Doudou. The second locality was 24.3 km 307° NW Doussala, 12.2 km 309° NW of the first locality, 2°13.35'S, 10°24.35'E, at an elevation of 350 m. The third locality was 25.2 km 304° NW Doussala, 1.36 km 253° WSW of the second locality, 2°13.63'S, 10°23.67'E, at an elevation of 630 m, 35 m below the highest peak of Monts Doudou. Sampling was carried out between 600 and 660 m. The habitat of all three localities comprised coastal lowland rain forest (White 1983). The first locality had been selectively logged up to 1992.

Sampling methods

The Ichneumonidae were sampled using Malaise traps, yellow pan traps, sweep netting and hand collecting at each of the sampled elevations (110 m, 350 m and 630 m) on Monts Doudou. A transect consisting of 25 stations, spaced at 5 m intervals was laid out at each sampled elevation. At each station a yellow plastic bowl (165 mm diameter × 40 mm depth) was placed on the forest floor and charged with propylene glycol. These yellow pan traps were left for seven days and serviced at the end of this period, with each station being retained as a separate sample. Four Malaise traps were deployed at each elevation and serviced each day for a period of seven days. The Malaise traps were constructed to the specifications of the Townes design (Townes 1972), and made with a fine-meshed netting (grid size 0.2 mm), with black walls and a white roof. Fifty samples, each sample comprising 20 net sweeps (each sweep encompassing an arc of 180°), i.e., 1000 sweeps, were carried out at each elevation. The collection of these samples was spaced over a period of seven days at each elevation. Each sweep was conducted in previously unsampled vegetation. The sweep net used for sampling was based on the design of Noyes (1982), with an opening area of ca. 1300 cm^2, and a collecting bag constructed from fine-meshed netting with a grid size of 0.2 mm. Sampling effort is portrayed in Table 1.

TABLE 1. Sampling effort for ichneumonid wasps across elevation on Monts Doudou (24 February to 21 March 2000).

	110 m	370 m	630 m
Malaise trap	28 trap days	28 trap days	28 trap days
Yellow pan trap	175 trap days	175 trap days	175 trap days
Sweeping	1000 sweeps	1000sweeps	1000 sweeps
Hand collecting	8 days	8 days	8 days

Identification and analyses

Specimens were identified to subfamily and to genus and in a few cases to species level. The majority of the specimens, however, were only sorted to morpho-species. Comparative species richness of the Ichneumonidae across elevation and between sampling methods was assessed by plotting smoothed, species-accumulation curves, also known as rarefaction curves (Gotelli and Colwell 2001), using the program EstimateS (Colwell 1997). An estimate of ichneumonid species richness present at the sampled localities, using the methods that were deployed during the survey and within the particular sampled season, was interpreted from the results of the abundance-based coverage estimator and incidence-based coverage estimator options within the program EstimateS. These estimators function on the principle that ". . . all the useful information about undiscovered classes lies in the rarer discovered classes" (Chazdon et al. 1998), and hence the abundance-based coverage estimator extrapolates estimates based on species with fewer than ten specimens in a sample and the incidence-based coverage estimator extrapolates estimates based on species that are present in ten or fewer sampling units (Colwell 1997). EstimateS was also used to compute the Shannon diversity index, which is based on the proportional abundance of species and combines richness with evenness (i.e., how equally abundant the species are) (Magurran 1988). Specimens resulting from all the deployed collection methods were included in the analyses. The collected material is deposited in the South African Museum, Cape Town. Representative specimens will be returned to Libreville, Gabon.

190

RESULTS

Two hundred and thirty-three specimens representing 112 species were collected on Monts Doudou. Forty-five of the 50 sampled genera were new records for Gabon. Thirteen subfamilies were represented in the collected material, only six of which had previously been recorded from Gabon. Table 2 lists the sampled species and their abundance at each of the sampled elevations. The smoothed, species-accumulation curves for total observed ichneumonid richness showed no indication of reaching an asymptote, when either plotted against sampling effort or against abundance (Figs. 1 and 2). Species richness estimates indicated that between 305 (ACE) and 312 (ICE) species should be expected on Monts Doudou using the same sampling methods during the same season (Fig. 1). From an abundance perspective the ichneumonids comprised 6.4% of the ca. 3650 hymenopteran specimens (excluding ants and reared fig wasps) that were sampled on Monts Doudou.

In terms of overall sampling effort, the mid-elevation site produced the highest species richness and abundance, followed by the high elevation site and lastly the low elevation site (Table 3, Fig. 3). Conversely, by plotting cumulative species against abundance rather than against sampling effort, and by assessing the shape (species return per individuals captured) of the smoothed, species-accumulation curve, a different pattern emerged. This approach indicated that, with increased sampling, the peak of Monts Doudou, followed by the mid-and low elevation sites, would be the most species rich of the three sampled sites, and was also the most diverse (richness in relation to abundance) site of the survey (Fig. 4). None of the smoothed, species-accumulation curves for the three sampled elevations on Monts Doudou approach an asymptote (Figs. 3 and 4). Estimates of species richness expected at these three elevations indicate an expected doubling to tripling of species richness (Table 3, Figs. 5 and 6).

Species turnover was high between elevations (Fig. 7). Eighty-two percent of the sampled species were unique to an elevation, with only 6% shared across all three elevations and between 1.8% and 6% of total species richness shared between any two elevations (Fig. 7). Strict complementarity across elevation, where species that are shared across all three elevations are included in the shared tally between any two elevations still showed a low complementarity between elevations, with between 8% and 12.5% of the total sampled species richness shared between any two given elevations (Table 4). The Morisita-Horn index of similarity depicted that low and high elevation was more similar than mid-and high elevation or low and mid-elevation (Table 4).

Of the four methods deployed to collect ichneumonid wasps, sweeping was the most efficient in terms of procured species richness and abundance, followed by Malaise trapping; yellow pan trapping was extremely inefficient, and was superseded by hand collecting (Table 5). Smoothed, species-accumulation curves showed that sweeping was the most efficient method in procuring species per sampling effort followed by hand collecting, Malaise trapping and lastly yellow pan trapping (Fig. 8). Conversely, plotting cumulative species against abundance showed that all four methods were similarly efficient in returning species per number of specimens captured (Fig. 9). Malaise trapping and hand collecting slightly superseded sweeping and yellow pan trapping. Species richness estimators indicated that the deployed sampling methods procured between 19 and 38 % of expected species richness (Table 5, Figs. 10 and 11).

TABLE 2. Ichneumonids sampled on Monts Doudou and their presence and abundance across the three elevations that were sampled.

Subfamily	Genus	Species	110 m	350 m	630 m	Total
Acaenitinae	*Paracollyria*	sp. 1	0	0	1	1
	Phorotrophus	sp. 1	0	1	0	1
	Phorotrophus	sp. 2	0	0	1	1
Anomalinae	*Bimentum*	sp. 1	2	0	0	2
Banchinae	*Apophua*	sp. 1	0	0	1	1
	Spilopimpla	sp. 1	0	0	1	1
Brachycertinae	Genus 1	sp. 1	0	0	1	1
Campopleginae	*Campoplex*	sp. 1	1	0	0	1
	Casinaria	sp. 1	0	4	0	4
	Casinaria	sp. 2	1	0	0	1
	Charops	sp. 1	3	1	0	4
	Chriodes	sp. 1	1	0	0	1
	Hyposoter	sp. 1	1	0	2	3
	Klutiana	sp. 1	1	0	0	1
	Olesicampe	sp. 1	0	0	1	1
	Xanthocampoplex	sp. 1	0	0	2	2
	Genus 1	sp. 1	1	0	0	1
Cremastinae	*Pristomerus*	sp. 1	1	0	0	1
	Pristomerus	sp. 2	1	0	0	1
	Pristomerus	sp. 3	1	0	0	1
	Trathala	sp. 1	2	0	0	2
Cryptinae	*Ateleute*	sp. 1	2	0	5	7
	Bodedia	sp. 1	0	1	2	3
	cf. *Bodedia*	sp. 1	1	0	0	1
	Bozakites	sp. 1	0	2	0	2
	Bozakites	sp. 2	1	0	0	1
	Chirotica	sp. 1	0	1	0	1
	Fitatsia	sp. 1	0	2	0	2
	Fitatsia	sp. 2	3	0	0	3
	cf. *Gabunia*	sp. 1	0	0	1	1
	Handaioa	sp. 1	0	1	0	1
	Handaoia	sp. 2	1	0	0	1
	Hoeocryptus	sp. 1	0	1	0	1
	Lienella	sp. 1	1	0	0	1
	Lienella	sp. 2	0	0	1	1
	Lienella	sp. 3	0	1	0	1
	Lienella	sp. 4	1	0	0	1
	Lienella	sp. 5	0	0	1	1
	cf. *Mamelia*	sp. 1	0	1	0	1
	cf. *Mamelia*	sp. 2	0	0	1	1

Table 2. continued.

Subfamily	Genus	Species	110 m	350 m	650 m	Total
	cf. *Mamelia*	sp. 3	0	3	0	3
	Mansa	sp. 1	0	0	1	1
	Nematocryptus	sp. 1	2	0	0	2
	Nematocryptus	sp. 2	1	0	0	1
	Nematocryptus	sp. 3	1	0	0	1
	Nematocryptus	sp. 4	1	0	0	1
	Nematocryptus	sp. 5	1	0	0	1
	cf. *Nematocryptus*	sp. 1	0	0	1	1
	cf. *Nematocryptus*	sp. 2	1	0	0	1
	Paraphylax	sp. 1	0	0	2	2
	Paraphylax	sp. 2	1	0	0	1
	Paraphylax	sp. 3	5	1	2	8
	Paraphylax	sp. 4	5	10	3	18
	Paraphylax	sp. 5	0	0	2	2
	Paraphylax	sp. 6	0	1	0	1
	Paraphylax	sp. 7	0	2	1	3
	Platymystax	sp. 1	1	0	0	1
	Platymystax	sp. 2	0	1	1	2
	Platymystax	sp. 3	0	0	1	1
	Platymystax	sp. 4	1	1	3	5
	Stenarella	sp. 1	1	0	0	1
	Tanyloncha	sp. 1	2	6	1	9
	Tanyloncha	sp. 2	0	0	2	2
	Tanyloncha	sp. 3	12	1	2	15
	Tanyloncha	sp. 4	1	0	0	1
	Genus 1	sp. 1	0	1	0	1
Ichneumoninae	*Aethioplitops*	*fulvator*	0	1	0	1
	Afrolongichneumon	sp. 1	0	0	1	1
	Afrolongichneumon	sp. 2	0	1	0	1
	Afrolongichneumon	sp. 3	0	1	0	1
	Afrolongichneumon	sp. 4	2	0	0	2
	Depressopyga	cf. *tanzanica*	0	0	1	1
	Foveosculum	*striatiferops*	1	0	0	1
	Gibbosoplites	*guineensis*	0	0	1	1
	Hemibystra	sp. 1	0	1	0	1
	Hemibystrops	cf. *vallatus*	1	0	0	1
	Oriphatnus	sp. 1	0	1	1	2
	Pseudotogea	*albidora*	0	1	0	1
	cf. *Rhadinodontops*	sp. 1	0	1	0	1
	Serratosculum	sp. 1	0	0	1	1
	Spinellamblys	sp. 1	0	0	1	1

TABLE 2. continued.

Subfamily	Genus	Species	110 m	350 m	650 m	Total
Ichneumoninae	Genus 1	sp. 1	0	0	1	1
	Genus 2	sp. 1	0	1	0	1
Mesochorinae	*Mesochorus*	sp. 1	1	1	0	2
	Mesochorus	sp. 2	0	1	1	2
	Mesochorus	sp. 3	0	2	0	2
	Mesochorus	sp. 4	0	2	0	2
	Mesochorus	sp. 5	0	1	0	1
	Mesochorus	sp. 6	0	2	0	2
	Mesochorus	sp. 7	0	2	0	2
Ophioninae	*Enicospilus*	*expeditus*	0	0	1	1
	Enicospilus	*senescens*	0	0	1	1
Orthocentrinae	*Chilocyrtus*	sp. 1	0	0	1	1
	Orthocentrus	sp. 1	0	1	0	1
	Orthocentrus	sp. 2	0	1	0	1
	Orthocentrus	sp. 3	0	1	0	1
	Orthocentrus	sp. 4	3	0	2	5
	Orthocentrus	sp. 5	2	9	2	13
	Orthocentrus	sp. 6	0	1	0	1
Pimplinae	*Xanthopimpla*	sp. 1	0	1	0	1
	Xanthopimpla	sp. 2	0	1	0	1
	Xanthopimpla	sp. 3	1	0	1	2
Tersilochinae	*Diaparsis*	sp. 1	0	1	0	1
	Diaparsis	sp. 2	0	3	1	4
	Diaparsis	sp. 3	1	0	0	1
	Diaparsis	sp. 4	3	2	1	6
	Diaparsis	sp. 5	0	0	2	2
	Diaparsis	sp. 6	0	1	0	1
	Diaparsis	sp. 7	0	1	0	1
	Diaparsis	sp. 8	0	1	0	1
	Sathropterus	sp. 1	0	5	1	6
Subfamily undet.	Genus 1	sp. 1	0	0	1	1
Total abundance			77	91	65	133

Species complementarity between different methods was low. Malaise trapping and sweeping had the highest species overlap, although this was still only 11% of the total sampled species richness and hence none of the methods made any other method redundant (Table 6, Fig. 12).

An ichneumonid species richness comparison with studies conducted elsewhere in the tropics and at increased latitude in the northern and southern hemisphere temperate regions is portrayed in Table 7.

DISTRIBUTION AND BIOLOGY OF ICHNEUMONIDAE FROM MONTS DOUDOU

Subfamily Acaenitinae: Tribe Acaenitini

Paracollyria Cameron

A single species of *Paracollyria* was collected at the top (660 m) of Monts Doudou. Nine species have been described from the Afrotropical region, two of which, *P. fenestrata* Kriechbaumer and *P. terebrator* Szépligeti, are known from Gabon (Townes and Townes 1973; Yu 1998). *Paracollyria* is confined to the Afrotropical region where species have also been recorded from Sierra Leone, Democratic Republic of the Congo (Zaire), Zimbabwe, and South Africa (Yu 1998). Biology of the genus is unknown, although hosts of other Acaenitini are wood-boring Coleoptera (Townes 1971).

Phorotrophus Saussure

Two species of this genus were collected on Monts Doudou, one from the peak (660 m) and the other from mid-elevation (350 m). Thirty-three described species of this Afrotropical genus are known from the region, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). The biology of *Phorotrophus* species is unknown.

Subfamily Anomalinae: Tribe Gravenhorstiini

Bimentum Townes

A single species of *Bimentum* was collected at low elevation (110 m) on Monts Doudou. This monotypical Afrotropical genus is only known from Sierra Leone (Yu 1998). Biology is unknown.

Subfamily Banchinae: Tribe Glyptini

Apophua Morley

A single species was trapped at the peak (660 m) of Monts Doudou. *Apophua* is a large genus present in the Nearctic, Palaearctic, Oriental, Australian and Afrotropical regions; thirteen species are known from the Afrotropical region, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). Members of the tribe Glyptini are parasitoids of lepidopteran larvae living in concealed situations, such as leaf rolls, cases, or tunnels in plant stems.

Tribe Atrophini

Spilopimpla Cameron

A single species of this genus was trapped on top (660 m) of Monts Doudou. Twenty described species are present in this Afrotropical genus, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). Members of the tribe Atrophini are parasitoids of lepidopteran larva.
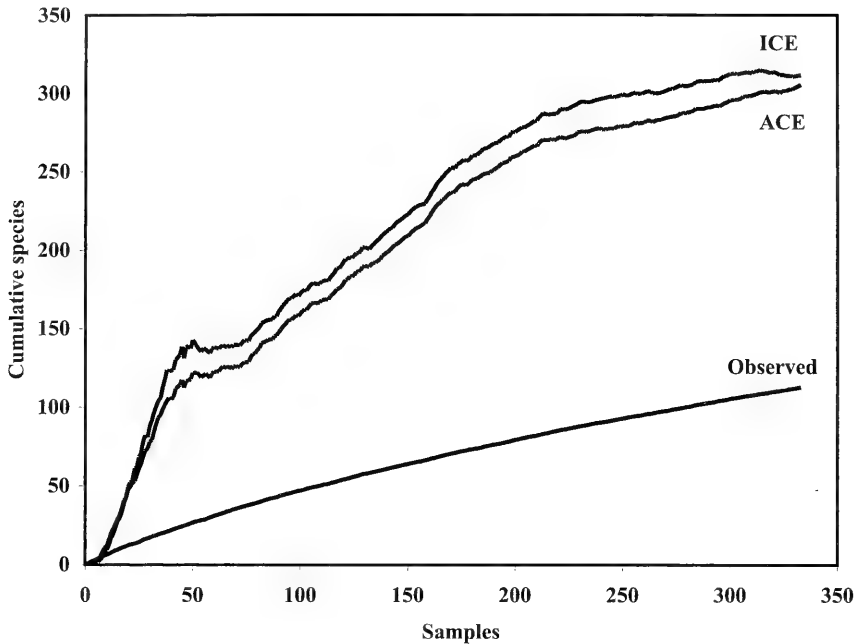
FIGURE 1. Observed and estimated cumulative ichneumonid species richness plotted against sampling effort on Monts Doudou. ACE = Abundance based coverage estimator. ICE = Incidence based coverage estimator.
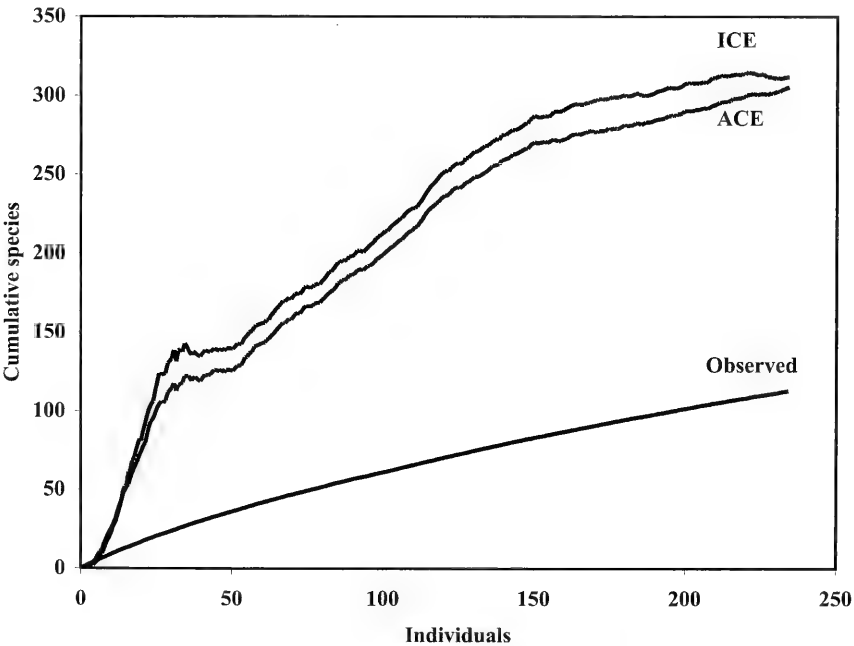
FIGURE 2. Observed and estimated cumulative ichneumonid species richness plotted against abundance on Monts Doudou. ACE = Abundance based coverage estimator. ICE = Incidence based coverage estimator.

TABLE 3. Observed species richness and abundance of ichneumonid wasps across elevation on Monts Doudou. Estimated expected species richnes [ICE–ACE] in brackets.

Altitude	Species	Individuals	Shannon index
110 m	43 [96–99]	77	3.45
350 m	50 [157–167]	91	3.60
630 m	46 [101–134]	65	3.74

TABLE 4. Species complementarity of ichneumonid wasps across elevation. Numbers above the asterisk denote shared species; numbers below the asterisk denote the Morisita-Horn similarity index.

Altitude	110 m	350 m	630 m
110 m	*	9	11
350 m	0.34	*	14
630 m	0.42	0.38	*

TABLE 5. Efficiency of sampling method in collecting ichneumonid wasps on Monts Doudou. Estimated species richness [ICE–ACE]

Method	Species	Individuals	% of total sampled richness
Malaise trap	36 [98–108]	51	32
Yellow pan trap	8 [21–22]	11	7
Sweeping	75 [286–297]	152	67
Hand collecting	16 [72–84]	19	14

TABLE 6. Species complementarity of ichneumonid wasps between different sampling methods. Numbers above the asterisk denote shared species; numbers below the asterisk denote the Morisita-Horn similarity index.

	Malaise trap	Sweeping	Yellow pan trap	Hand collecting
Malaise trap	*	12	3	1
Sweeping	0.27	*	4	6
Yellow pan trap	0.11	0.19	*	1
Hand collecting	0.02	0.15	0.04	*

Subfamily Brachycyrtinae

Genus undet.

A single female was swept near the top of Monts Doudou (600 m). This does not fit any of the described world genera of this subfamily. The only genus recorded from the Afrotropical region is *Brachycyrtus* Kriechbaumer (Townes and Townes 1973).

Subfamily Campopleginae

Campoplex Gravenhorst

A single species of *Campoplex* was collected at low elevation (110 m). This is a cosmopolitan genus with two species recorded from the Afrotropical region (South Africa) (Townes and Townes 1973; Yu 1998). *Campoplex* species attack lepidopteran larvae.

Casinaria Holmgren

Two species of this genus were collected on Monts Doudou, one at low elevation (110 m) and the other at mid-elevation (350 m). *Casinaria* is cosmopolitan,with two described species present in the Afrotropical region, neither recorded from Gabon (Townes and Townes 1973; Yu 1998). Species of *Casinaria* are parasitoids of lepidopteran larvae.

Charops Holmgren

A single species of this genus was collected at low (110 m) and mid-elevation (350 m). *Charops* is a cosmopolitan genus centered in the tropics with 11 species recorded from the Afrotropical region, none of which are known from Gabon (Townes and Townes 1973; Yu 1998). *Charops* species are parasitoids of lepidopteran larvae.

Chriodes Foerster

A single species of *Chriodes* was trapped at low elevation (110 m). Three species of this Old World tropical genus are known from the Afrotropical region, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). Biology of the species is unknown.

Hyposoter Foerster

One species of this genus was collected at both low (110 m) and high (660 m) elevation. *Hyposoter* is a cosmopolitan genus with three described species present in the Afrotropical region, none of which have yet been recorded from Gabon (Townes and Townes 1973; Yu 1998). Species of *Hyposoter* are parasitoids of lepidopteran larva.

Klutiana Betram

A single species was swept at low elevation (110 m). A single species of this Old World tropical genus is known from the Afrotropical region (Kenya) (Townes and Townes 1973; Yu 1998). Host relationships of *Klutiana* species are unknown.

Olesicampe Foerster

A species of this genus was trapped on the peak (660 m) of Monts Doudou. *Olesicampe* is a predominantly Holarctic genus with representatives in the Oriental and Afrotropical regions; no species have yet been described from the Afrotropical region
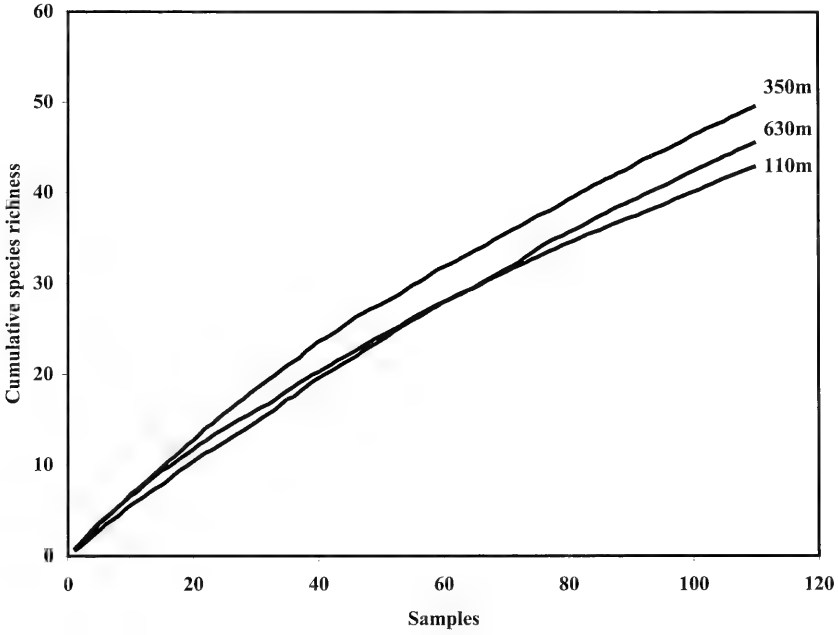
FIGURE 3. Observed spatial species richness patterns, plotted as cumulative species richness against sampling effort, of Ichneumonidae on Monts Doudou as determined by elevation.
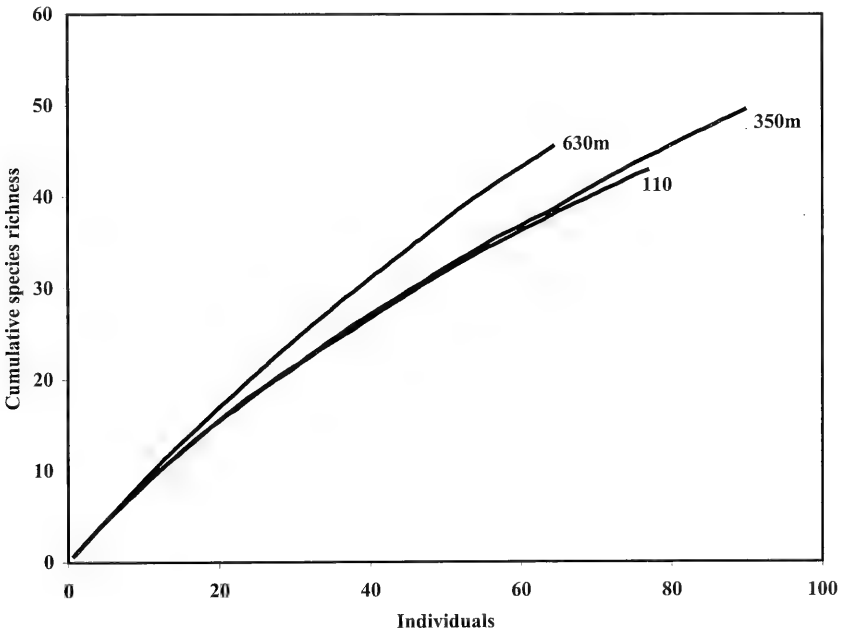
FIGURE 4. Observed spatial species richness patterns, plotted as cumulative species richness against individuals, of Ichneumonidae on Monts Doudou as determined by elevation.
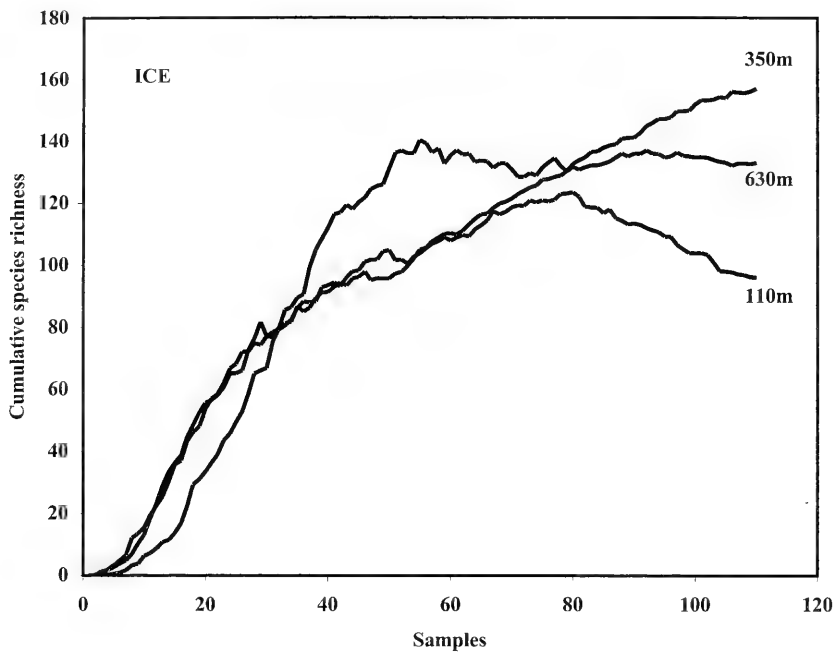
FIGURE 5. Incidence based coverage species richness estimates (ICE) of the Ichneumonidae for the three sampled elevations on Monts Doudou.
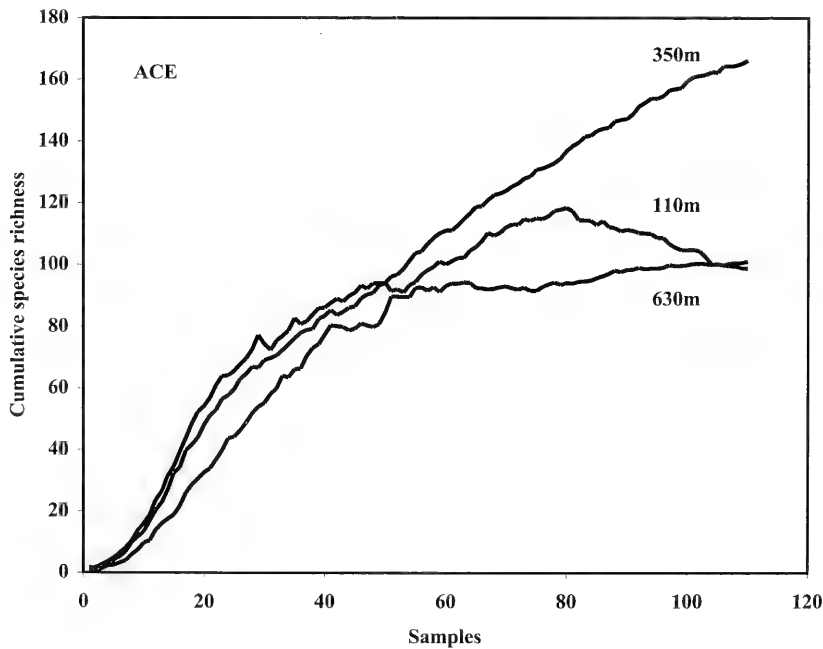
FIGURE 6. Abundance based coverage species richness estimates (ACE) of the Ichneumonidae for the three sampled elevations on Monts Doudou.

600-660m
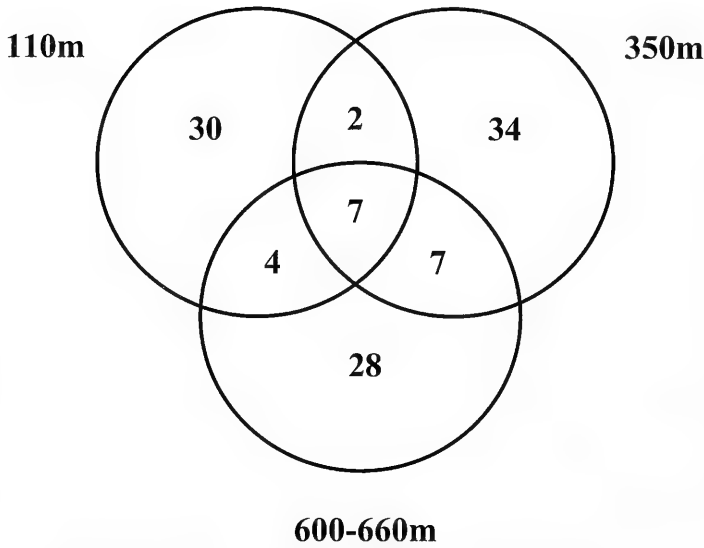
FIGURE 7. Venn diagram illustrating ichneumonid species richness across elevation on Monts Doudou: number of species unique to elevation, number of species shared between elevation pairs and number of species shared between all three elevations.

(Townes and Townes 1973; Yu 1998). Hosts of species of this genus are sawflies (Tenthredinidae, Hymenoptera).

Xanthocampoplex Morley
    A single species was collected on the top of Monts Doudou (660 m). *Xanthocampoplex* is a cosmopolitan genus, with a single species described from the Afrotropical region (Kenya, South Africa) (Townes and Townes 1973; Yu 1998). Hosts of this genus are lepidopteran larva.

Genus undet.
    A male of an unidentified campoplegine genus was swept at low elevation (110 m).

Subfamily Cremastinae

Pristomerus Curtis
    Three species of *Pristomerus* were collected at low elevation (110 m). *Pristomerus* is another large, cosmopolitan, mostly tropical genus, with eight described species known from the Afrotropical region, none of which have been recorded from Gabon (Yu 1998). Species of *Pristomerus* are endoparasitoids of concealed lepidopteran larvae living in tunnels, leaf rolls, or buds (Townes 1971).

Trathala Cameron
    A single species of *Trathala* was collected at low elevation (110 m). This is a large cosmopolitan genus with eight species recorded from the Afrotropical region, none of which are known from Gabon (Townes and Townes 1973; Yu 1998). Species of *Trathala* are endoparasitoids of lepidopteran (usually Pyraloidea) larva (Townes 1971).
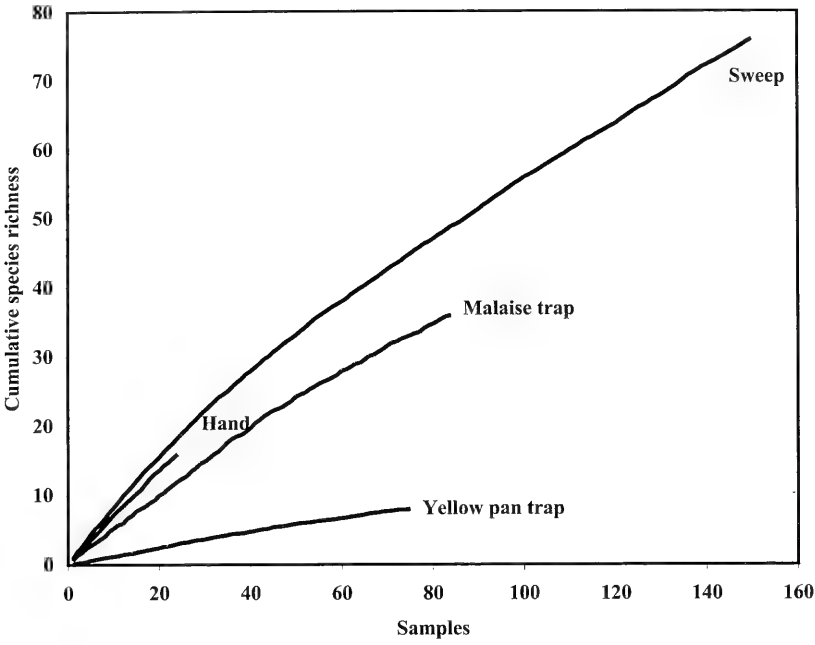
FIGURE 8. Observed hymenopteran species richness patterns between the different sampling methods deployed on Monts Doudou per unit sampling effort.
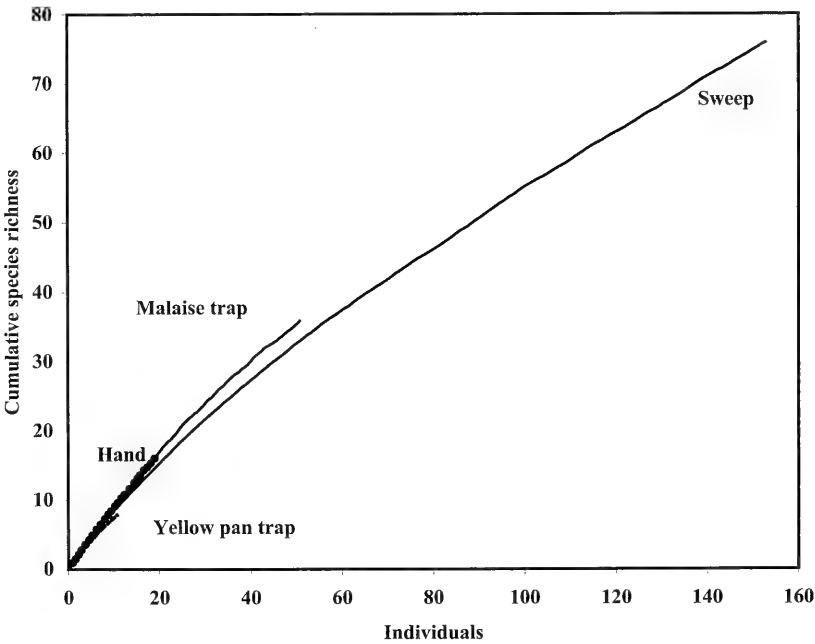
FIGURE 9. Observed hymenopteran species richness patterns between the different sampling methods deployed on Monts Doudou per sampled specimens.
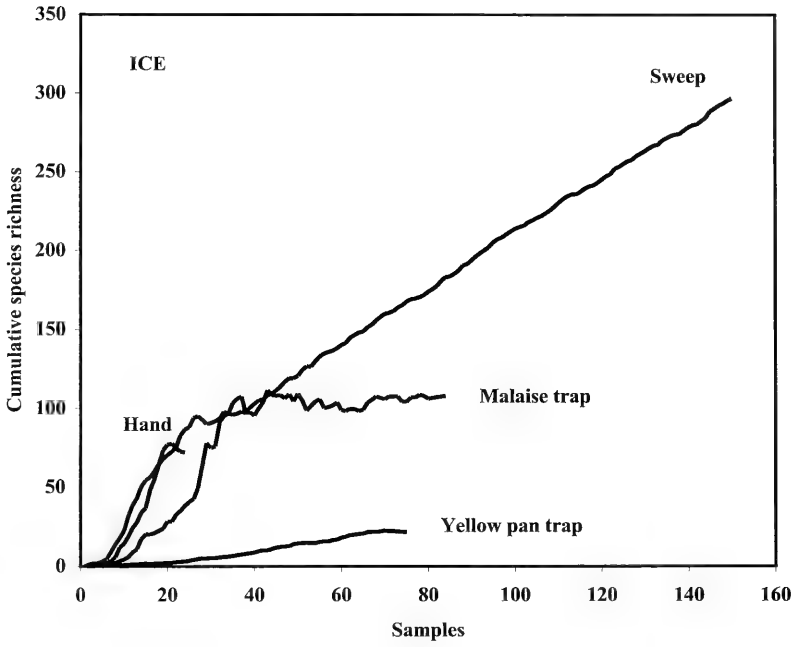
FIGURE 10. Incidence based coverage species richness estimates (ICE) for the different methods deployed to sample ichneumonids on Monts Doudou.
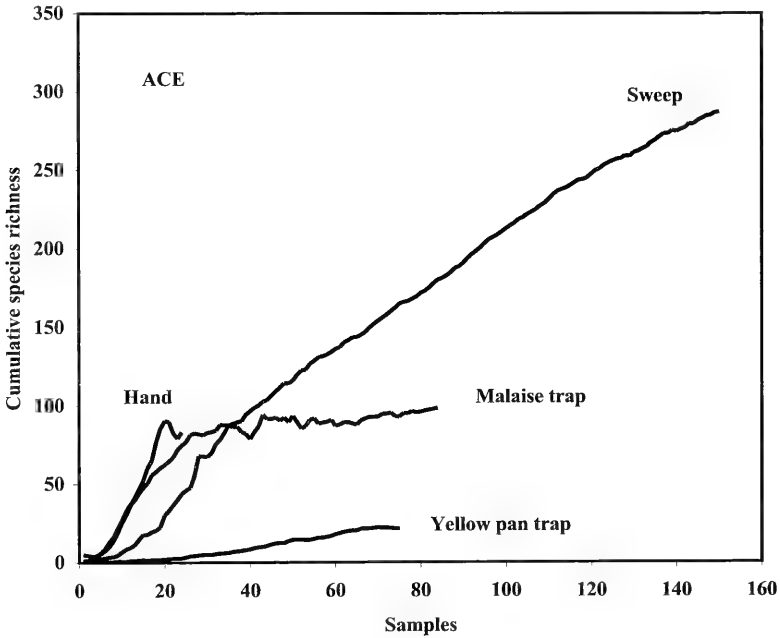
FIGURE 11. Abundance based coverage species richness estimates (ACE) for the different methods deployed to sample ichneumonids on Monts Doudou.

Subfamily Cryptinae: Tribe Cryptini

Ateleute Foerster

A single species of *Ateleute* was collected at both low (110 m) and high (600-660 m) elevation. This cosmopolitan genus is centered in the Old World tropics, with 24 species known from the Afrotropical region, all of these except for one recorded from Madagascar (Townes and Townes 1973; Yu 1998). None are known from Gabon. The only recorded hosts are Psychidae (Lepidoptera).

Bozakites Seyrig

Two species of *Bozakites* were hand collected or swept at low and mid-elevation. Seven described species of this Afrotropical genus are known from Madagascar, Tanzania, Guinea, Liberia, and South Africa (Townes and Townes 1973; Yu 1998), although there are at least 41 species present in museum collections (Townes 1969). Biology is unknown.

Fitatsia Seyrig

This genus was represented by two species on Monts Doudou. Four of the five specimens were hand collected, the other swept. *Fitatsia* is an Afrotropical and Oriental genus with only a single Afrotropical species described from Madagascar (Townes 1969; Yu 1998). Biology is unknown.

cf. *Gabunia* Kriechbaumer

A single female belonging to a probably undescribed genus that is near to *Gabunia* Kriechbaumer was collected by hand at the top of Monts Doudou (660 m). The new genus shares characters, in part, with three related described genera: *Gabunia* Kriechbaumer 1895 (6 species from central and east Africa, 3 of which have been recorded from Gabon), *Anepomias* Seyrig 1952 (monotypic, Madagascar) and *Schreineria* Schreiner 1905 (2 species, South Africa and Madagascar) (Townes and Townes 1973; Yu 1998). Species of *Schreineria* are distributed through the Palaearctic, Oriental and Afrotropical regions and are parasitoids of cossid, aegeriid and cerambycid larvae that bore in trees; biology of *Anepomias* and *Gabunia* (both genera are restricted to the Afrotropical region) is unknown (Townes 1969), but they are also likely to attack larvae concealed in wood, a feeding behavior that is characteristic of related genera (Gupta and Gupta 1983).

Hoeocryptus Habermehl

A single species was swept at mid-elevation (370 m). *Hoeocryptus* is an Afrotropical genus, with 7 described species occurring in Madagascar, east and west Africa, with none known from Gabon (Yu 1998). Biology is unknown.

Nematocryptus Roman

Five species of *Nematocryptus* were collected at the base of Monts Doudou (110 m). Eight species have been described from the Afrotropical region, with a widespread species, *N. pallidus* Kriechbaumer, recorded from Gabon (Townes and Townes 1973; Yu 1998). This is a predominantly Afrotropical genus with an additional two species described from India; biology of the genus is unknown (Townes 1969).
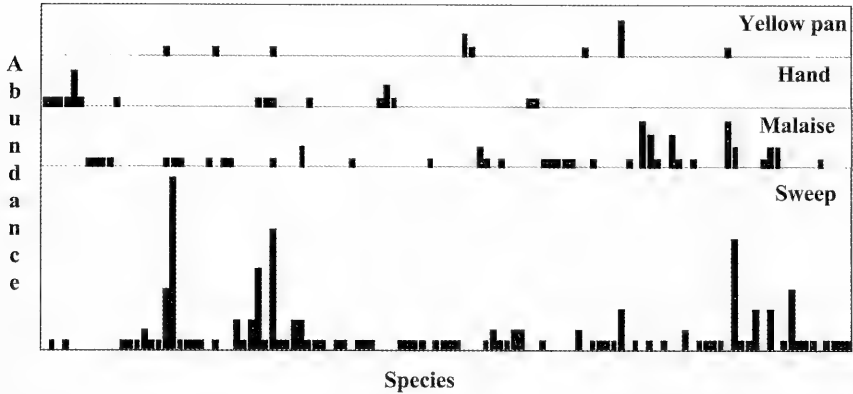
FIGURE 12. Histograms illustrating complementarity of ichneumonid species between the four deployed collecting methods.

cf. *Nematocryptus* Roman

Two species that may represent an undescribed genus, close to *Nematocryptus* were collected at 110 m and 600 m, respectively.

Stenarella Szépligeti

A single species of *Stenarella* was collected at the base of Monts Doudou (110 m). The genus is known from three described species in the Afrotropical region, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). *Stenarella* is distributed throughout the tropics and subtropics in the Old World, but is centered in the Afrotropical region; biology of the genus is unknown (Townes 1969).

Tanyloncha Townes

Four species of this genus were collected across all three sampled elevations, mostly by sweeping, but several specimens were collected by hand, in Malaise traps or yellow pan traps; one was taken at UV light. *Tanyloncha* is a monotypical genus recorded from Congo and the Democratic Republic of the Congo (Townes and Townes 1973; Yu 1998). Biology of the genus is unknown.

Tribe Aptesini

Mansa Tosquinet

A single male of this genus was collected in a Malaise trap at 600 m. *Mansa* is a large Old World tropical genus, with 7 described species from the Afrotropical region (Democratic Republic of the Congo, Equatorial Guinea, Cameroon, Rwanda, and Tanzania) (Townes and Townes 1973; Yu 1998). Biology is unknown.

Platymystax Townes

Four species of *Platymystax* were collected on Monts Doudou. The genus was represented across all three sampled elevations. Two described species are known from the Afrotropical region (Togo and Guinea) (Townes and Townes 1973; Yu 1998). This is a large pantropical genus; biology is unknown (Townes 1969).

TABLE 7. Recorded global ichneumonid species richness. Figures in square brackets represent the estimated species richness (using EstimateS). Data from Owen and Owen (1974)[1], Owen et al. (1981)[2], Sawoniewicz (1979[3]; 1986[4]), Noyes (1989b)[5], van Noort et al. (2000)[6], van Noort (in prep.)[7] and van Noort and Fisher (in prep.)[8]. MT = Malaise trap, SW = sweeping, YP = yellow pan trap, WL = Winkler bag extraction of leaf litter, PT = pitfall trap, FI = flight intercept trap, LT = UV light trap, CF = tree canopy fogging, CM = tree canopy misting.

COUNTRY	LATITUDE	METHODS	SAMPLING PERIOD	NUMBER OF SPECIES	NUMBER OF SPECIMENS	MARGALEF'S DIVERSITY INDEX
Gabon	2°S	MT, YP, SW	4 weeks	112 [312]	233	20.36
Sierra Leone[1]	8°N	MT	15 months	319	1979	41.90
Uganda[1]	19°N	MT	18 months	293	2268	37.79
Tanzania[7]	4°S	MT, YP, SW, LT, CM, WL, PT	6 weeks, 1MT 5 months	183 [419]	563	28.89
Namibia[6]	21°S	MT, YP, SW, WL	6 weeks	28	53	7.05
South Africa[8]	30°S	MT, YP, SW, WL, PT	5 days	88 [175]	1849	11.53
Sulawesi[5]	1°N	MT, YP, SW, FI, CF	2 months	420	4373	49.98
England[2]	52°N	MT	28 months	326	2495	41.55
England[1]	52°N	MT	9 months	529	9666	57.54
Poland[3]	52°N	SW, YP	14 months	680	12203	72.16
Poland[4]	52°N	YP	4 seasons	392	7920	43.55
Sweden[1]	59°N	MT	6 months	758	10994	81.35

Tribe Phygadeuontini: Subtribe Chiroticina

Bodedia Seyrig
  This genus was represented by a single species, swept at mid- and high elevation. *Bodedia* was known previously only from Madagascar, represented by 13 described species (Townes and Townes 1973; Yu 1998). Biology is unknown.

cf. *Bodedia* Seyrig
  A species representing an undescribed genus close to *Bodedia* was swept at low elevation (110 m).

Chirotica Foerster
  A single species of this genus was collected in a Malaise trap at mid-elevation (350 m). This cosmopolitan genus is represented by a single species in the Afrotropical region (Madagascar) (Townes and Townes 1973; Yu 1998). Species of *Chirotica* are parasitoids of Psychidae (Lepidoptera).

Handaoia Seyrig
  This genus was represented by two species, collected at low and mid-elevation respectively. *Handaoia* has a fragmented distribution (South Africa, Tanzania, Madagascar, Philippines, Japan, and Peru) (Townes 1969). Only the Madagascan (seven species) and Tanzanian (one species) species are described (Townes and Townes 1973; Yu 1998). Biology is unknown.

Lienella Cameron
  Lienella was represented by five species, all singletons that were mostly swept, except for one that was hand collected. This large, Old World, tropical genus contains 17 described Afrotropical species, mostly from Madagascar, but also South Africa and Tanzania (Townes and Townes 1973; Yu 1998). Biology is unknown.

cf. *Mamelia* Seyrig
  Three species of a genus close to *Mamelia* were swept or collected in a Malaise trap. *Mamelia* contains a single described species from Madagascar (Townes and Townes 1973; Yu 1998). Biology is unknown.

Paraphylax Foerster
  Seven species of this large, mostly Old World, tropical genus were collected across all elevations. Sweeping collected most specimens, but Malaise traps and yellow pan traps also produced material. From an abundance perspective this was the most common genus on Monts Doudou (representing 14% of total abundance), and was also one of the more species rich genera. Thirty-three species have been described, mostly from Madagascar, but also South Africa, Burundi and Tanzania (Townes and Townes 1973; Yu 1998). *Paraphylax* species are mostly parasitoids of cocoons (such as other ichneumonids and spider egg cocoons); some species are parasitoids of Psychidae (Lepidoptera) (Townes 1969).

Genus undet.
  A single male of an unidentified cryptine genus was swept at low elevation.

Subfamily Ichneumoninae

Aethioplitops Heinrich

A female of *Aethioplitops fulvator* (Morley) was collected at mid-elevation (350 m). This species is known from Uganda, Kenya, Angola, and Guinea (Heinrich 1968a). *Aethioplitops* is an African genus that occurs from South Africa to Guinea, and contains four described species (Townes and Townes 1973; Yu 1998). Biology is unknown.

Afrolongichneumon Heinrich

Four undescribed species of *Afrolongichneumon* were collected on Monts Doudou, all represented by females. One species was swept at 600 m, another at 370m; the third species was collected in a Malaise trap at 350m and the last in yellow pan traps at 110 m. This is an Afrotropical genus represented by 6 described species, with a generic distribution covering Madagascar, and east, central and west Africa (Townes and Townes 1973; Yu 1998). The genus has not previously been recorded from Gabon. Biology is unknown.

Depressopyga Heinrich

A female of an undescribed species close to *Depressopyga tanzanica* Heinrich was swept on the peak of Monts Doudou (660 m). Only three specimens, each representing a species of *Depressopyga*, are known from Zambia, Tanzania, and Uganda respectively (Heinrich 1968b; Yu 1998). Biology is unknown.

Foveosculum Heinrich

A female of *Foveosculum striatiferops* Heinrich was hand collected at the base of Monts Doudou (110 m). The species is known only from the female holotype collected in Equatorial Guinea. *Foveosculum* is Afrotropical in distribution and is one of the characteristic genera of the region (Heinrich 1967c), containing 24 described species, none of which have previously been recorded from Gabon (Townes and Townes 1973; Yu 1998). Biology is unknown.

Gibbosoplites Heinrich

A single female of *Gibbosoplites guineensis* Heinrich was hand collected at the peak of Monts Doudou (660 m). The species is known only from the holotype collected in Equatorial Guinea (Heinrich 1968a; Townes and Townes 1973). *Gibbosoplites* is a tropical African genus with 3 species recorded from Togo, Equatorial Guinea, Democratic Republic of Congo (Zaire), and Uganda (Heinrich 1968a; Yu 1998). Biology is unknown.

Hemibystra Heinrich

An undescribed species of *Hemibystra* was swept at mid-elevation (370 m). *Hemibystra* is an Afrotropical genus with 24 described species recorded mostly from east and southern Africa (Townes and Townes 1973; Yu 1998). This is the first record of the genus from Gabon. Biology is unknown.

Hemibystrops Heinrich

A female of an undescribed species of *Hemibystrops*, close to *H. vallatus* (Morley), was swept at the base of Monts Doudou (110 m). This is a monotypical genus recorded from South Africa, Tanzania, and Uganda (Townes and Townes 1973; Yu 1998). Biology is unknown.

Pseudotogea Heinrich

A female of *Pseudotogea albidora* Heinrich was swept at mid-elevation (370 m). This species was described from a single specimen collected in northwestern Angola (Heinrich, 1968a). *Pseudotogea* is a rain forest genus with five described species that occur in lowland rain forest in Central Africa (Angola) and Afromontane forest in east and southern Africa (Uganda, Tanzania, and South Africa). Biology is unknown.

cf. *Rhadinodontops* Heinrich

A female of an undescribed genus that shares some characters with *Rhadinodontops* was swept at mid-elevation. *Rhadinodontops* is a monotypical genus recorded from Uganda and South Africa (Heinrich 1968b; Yu 1998).

Serratosculum Heinrich

A female of an undescribed species was swept on the peak of Monts Doudou (660 m). *Serratosculum* is only known from the holotype male of *S. flavonigrum* Heinrich that was collected in Equatorial Guinea (Heinrich 1968b). Biology is unknown.

Spinellamblys Heinrich

An undescribed species, represented by a single female, was collected in a Malaise trap at 600 m. *Spinellamblys* is a monotypical genus previously only recorded from Uganda (Heinrich 1968b; Yu 1998). Biology is unknown.

Oriphatnus Heinrich

Two females, representing a single species, were hansd collected at 350 m and 660 m on Monts Doudou. *Oriphatnus* is represented by two species, so far only found in Equatorial Guinea, Cameroon, Uganda, and Angola (Heinrich 1967c; Yu 1998). Biology is unknown.

Genera undet.

Two females, each representing an unidentified ichneumonine genus, were collected on Monts Doudou.

Subfamily Mesochorinae

Mesochorus Gravenhorst

Seven species of *Mesochorus* were collected on Monts Doudou. One species was present across all three sampled elevations; another species at mid-and top elevation, and the remaining five species were only collected at mid-elevation. Twenty-five described species are known from the Afrotropical region with none yet recorded from Gabon (Yu 1998). This is a large cosmopolitan genus. The subfamily includes nine genera, three of which are present in the Afrotropical region (Yu 1998). Mesochorine species are hyperparasitoids, most commonly of Ichneumonoidea, but a few attack Tachinidae (Diptera).

Subfamily Ophioninae: Tribe Enicospilini

Enicospilus Stephens

Two species of *Enicospilus*, *E. senescens* (Tosquinet), and *E. expeditus* (Tosquinet), were collected on top of Monts Doudou (at 600 m and 660 m respectively). *Enicospilus*

senescens is a widely distributed species in the Afrotropical region, but most common in central and east Africa and has previously been recorded from Gabon (Mvoung, Mt. Sable); a recorded host is *Anomis leona* Schaus (Lepidoptera: Noctuidae) (Gauld and Mitchell 1978). *Enicospilus expeditus* is also a widely distributed species from equatorial Africa to Yemen and Madagascar, but not yet recorded from Gabon; the species has been reared from an unidentified lepidopteran pupa (Gauld and Mitchell 1978). There are 152 described species of *Enicospilus* in the Afrotropical region, 7 of which have been recorded from Gabon (Yu 1998).

Subfamily Orthocentrinae

Chilocyrtus Townes

A single species of this genus was sampled at the peak (660 m) of Monts Doudou. One species has been described from the Afrotropical region (Madagascar) (Townes and Townes 1973; Yu 1998). Biology is unknown.

Orthocentrus Gravenhorst

Six species of *Orthocentrus* were collected on Monts Doudou, of which four were sampled at mid-elevation (350 m), one at low (110 m) and high (660 m) elevation and the last species across all three elevations. This is a large cosmopolitan genus, with 14 described species known from the Afrotropical region, none of which have been recorded from Gabon (Townes and Townes 1973; Yu 1998). There are very few rearing records, but the Mycetophilidae and Sciaridae (Diptera) have been recorded as hosts.

Subfamily Pimplinae: Tribe Pimplini

Xanthopimpla Saussure

Three species of *Xanthopimpla* were recorded from Monts Doudou, two from mid-elevation (350 m) and one from both low (110 m) and high (600 m) elevation. Forty-three species have been described from the Afrotropical region, three of which have been recorded from Gabon: *X. occidentalis* Krieger, *X. octonotata* Krieger, and *X. ogovensis* (Dalla Torre) (Townes and Townes 1973; Yu 1998). This cosmopolitan genus is centered in the Old World tropics; biology of the genus is unknown.

Subfamily Tersilochinae

Diaparsis Foerster

Eight species of *Diaparsis* were collected, four at mid-elevation (350 m), one each at low and high elevation, one at mid-and high elevation and one across all three elevations. This is a large genus that has an almost worldwide distribution with the exception of the Neotropical and Australian regions. *Diaparsis* is centered in the Afrotropical region, but only two of the many species have been described from there (Townes and Townes 1973; Yu 1998). Species of *Diaparsis* are parasitoids of coleopteran larvae, particularly Curculionidae.

Sathropterus Foerster

A single species of this genus was collected at mid- and high elevation. This is a monotypical genus with the single, widespread, Old World species recorded from South

Africa in the Afrotropical region (Townes and Townes 1973, Yu 1998). Biology is unknown.

Subfamily undet.

A single male that could not be placed at subfamily level was collected in a Malaise trap on the peak of Monts Doudou.

DISCUSSION

In the context of global ichneumonid species richness and abundance, based on the observed species richness during this survey, the Ichneumonidae is fairly depauperate on Monts Doudou (Table 7). There is a dramatic disparity in richness compared with surveys conducted in the Northern Hemisphere temperate regions (Owen and Owen 1974; Owen et al. 1981; Sawoniewicz 1979, 1986), and in the Indo-Australasian tropics (Noyes 1989b). In an Afrotropical context, Monts Doudou is richer than two southern temperate localities in Africa (van Noort et al. 2000, van Noort and Fisher in prep.), and with increased sampling effort would probably approach or supersede the species richness recorded from the other three tropical African localities (Uganda, Sierra Leone and Tanzania) that have been far more comprehensively surveyed for Ichneumonidae (Owen and Owen 1974; van Noort in prep.). The Gabon inventory was a short-term survey and the shape of the species-accumulation curve and the species richness estimators illustrated that the Ichneumonidae had not been sampled sufficiently. The sampling effort of a summed total of only three Malaise trap months at three sites on Monts Doudou is clearly inadequate in assessing species richness of the ichneumonid fauna at this locality. Ichneumonid taxa can be rare and localised in distribution, as exemplified by two Costa Rican genera: 1473 Malaise trap months collected only 106 specimens representing six species of *Cryptophion* Viereck, the majority of the specimens being collected at a few of the many sites sampled in Costa Rica (Gauld and Janzen 1994) and 15 years of Malaise trapping produced only 4 specimens of *Arotes pammae* Gauld (Gaston et al. 1996). The thousand sweeps conducted at each elevation during this survey were expected to be sufficient to sample the ichneumonid fauna associated with the forest undergrowth and low canopy using this method. In a sweep survey of foliage inhabiting beetles and bugs in Costa Rica, 800 sweeps were usually sufficient to produce a levelling off of the species-accumulation curves (Janzen 1973a). However, in this study the accumulation curve for sweep sampling was still steadily rising, both as a function of samples and individuals, indicating that a thousand sweeps were inadequate in sampling ichneumonids in this habitat. The collecting methods that were deployed on Monts Doudou restricted sampling to the forest undergrowth and low forest canopy that was accessible in clearings and along paths. Hence, the forest canopy at a height of 40-50m (Sosef, this volume) was not sampled. The proportion of the ichneumonid faunal assemblage that resides in the canopy in Afrotropical rain forest habitats is simply not known, but it is likely that the use of tree canopy fogging, or misting with a knockdown pyrethroid insecticide, to sample this component of the forest would increase the species richness total for Monts Doudou. The forest canopy has been shown to harbor a high diversity of vascular epiphytes and arthropods (Wolda 1979; Erwin 1982; Stork 1991; Nadkarni 1994), and Basset and colleagues (2001) showed that density and abundance of many arthropod taxa was higher in the canopy than in the understory. However, Gauld and Gaston (1995) suggest that, based on species emanating from limited samples taken from the forest canopy in comparison to species assemblages from extensive Malaise trapping at

ground level during the INBio program in Costa Rica, there is not a large unsampled hymenopteran canopy fauna. Whether or not the canopy fauna was under sampled in this survey, a baseline inventory assessment of a local ichneumonid faunal assemblage has been provided for a country that has been extremely poorly surveyed for Hymenoptera. Only 25 ichneumonid species in 14 genera were previously recorded from Gabon (Yu 1998). The survey of Monts Doudou added a further 45 genera to the ichneumonid checklist for Gabon. Given the poor taxonomic resources for identifying ichneumonids, it was generally not feasible to identify the collected specimens to species level. The Ichneumonidae is one of the most species rich families of all organisms, but with only an estimated 15% of more than 12,000 species in the Afrotropical region known to science, existing species level identification keys are largely useless. For many taxa identification keys do not exist or where they do they are outdated and poorly backed up with pertinent illustrations. For this reason the examination of type specimens is necessary for reliable identity. Due to the logistic constraints the majority of species were only sorted to morpho-species, with the result that it is difficult to predict the number of undescribed species that were collected or the number of new species records for the country. Even so it was established that a number of undescribed species and genera were produced during this survey, and no doubt the majority of sampled species were new records for Gabon.

As a general rule species richness towards the tropics increases for many invertebrate taxa. In contrast, species richness of the Ichneumonidae is fairly constant across latitude. Three hypotheses, which probably work in conjunction, have been forwarded to explain this apparent anomaly. The resource fragmentation hypothesis maintains that tropical lepidopteran species may be too rare for utilization by specialist parasitoids (Janzen and Pond 1975; Janzen 1981). The predation hypothesis predicts that predation of parasitized hosts is more severe in the tropics (Rathcke and Price 1976), whereas, the nasty-host hypothesis is based on the fact that tropical tree species are in general richer in toxic compounds than temperate species. Caterpillars sequester toxins from their food-plants and therefore tropical species are likely to be better chemically defended against parasitoids than those in temperate regions (Gauld et al. 1992; Gauld and Gaston 1994). The results emanating from Monts Doudou support the tenet of a relatively depauperate, tropical, ichneumonid fauna in comparison to the increased tropical diversity of many other invertebrate taxa, including those that are hosts to parasitic ichneumonid wasps.

Assessments of species richness parameters can vary, depending on whether these are interpreted from sample-based or individual-based rarefaction analyses (Gotelli and Colwell 2001). This is clear from the comparative elevation results presented in this paper with the shape of the rarefaction curves changing, depending on whether cumulative species are plotted as a function of samples or individuals. Although strictly speaking the validity of species richness comparisons depends on the rarefaction curve reaching an asymptote, this is never achieved in invertebrate sampling (Fisher 1999). Hence, it is critical that appropriate scaling of the curves is implemented for comparative, species richness assessments (Gotelli and Colwell 2001). Sample-based data accounts for natural levels of taxon patchiness in the samples, but this preferred data set should still be plotted as a function of the accumulated number of individuals, because of the disparity in the mean number of individuals per sample (Gotelli and Colwell 2001).

Different sampling methods target different species, and hence are biased and non-random (Boulinier et al. 1998), and therefore not strictly comparable. However, it is possible to compare method efficiency in terms of species return per number of individuals that need to be processed (Longino and Colwell 1997). In this case the rarefaction curve

needs to be plotted as a function of individuals. Sampling units are temporally and spatially disparate between the different methods and hence comparison of methods based on this parameter leads to erroneous conclusions. This is clear when comparing Figures 8 and 9. Conversely to the results presented in Figure 8, Malaise trapping and hand collecting are more efficient than sweeping in terms of returning species per number of captured individuals. Malaise trapping, however, would require a dramatic increase in replication to return a species richness similar to sweeping over the same period of time. Fisher (1999) showed that a doubling of sampling effort with respect to a 25-station Winkler bag extraction of leaf litter transect would only produce a 11–20% increase in ant species richness. Assuming that a 20% increase would hold for Malaise trap sampling as well, to return a similar species richness to sweeping, each sampled locality would require an exponential increase in deployed Malaise traps from four to 64. Thus, in terms of maximizing species return from a logistic perspective, sweeping is more efficient than Malaise trapping in lowland rain forest. However, it needs to be born in mind that the type of habitat that is being sampled can influence method efficiency. Sweeping is practically redundant in many arid habitats, where the vegetation is sparse and thorny, as shown in a survey of the Brandberg massif in Namibia (van Noort et al. 2000).

The ichneumonids in the Gabon survey comprised 6.4% of the total hymenopteran abundance that was sampled by Malaise traps, Yellow pan traps, and sweeping, excluding the ants. This is in stark contrast to the situation in the Northern Hemisphere, where ichneumonids comprise around 15–20% of the hymenopteran fauna in temperate samples, for example 19.4% in a study in Spain (Segade et al. 1997). The Gabon ichneumonid component is more in line with other tropical rain forest studies, such as the 7.4% recorded in Sulawesi (Noyes 1989a). In contrast, tropical and subtropical African savannas appear to support lower ichneumonid abundance. Ichneumonidae comprised 2.4% of the total hymenopteran abundance (excluding ants) in a five-week survey of Mkomazi Game Reserve in northeastern Tanzania where a 183 ichneumonid species represented by 563 individuals were collected (S. van Noort in prep.). A six-week hymenopteran inventory survey on the Brandberg Massif situated in the arid Namib Desert Biome in northwestern Namibia produced 28 species represented by 53 specimens of Ichneumonidae, which from an abundance point of view comprised between 1.6–1.7% of the total hymenopteran specimens that were collected (van Noort et al. 2000). In an inventory survey of a temperate Southern Hemisphere locality that comprised fragmented Afromontane forest and adjoining moist upland grassland in Kwazulu-Natal (South Africa), the Ichneumonidae comprised 32.5% of the total hymenopteran abundance (excluding ants), but had a low species richness—88 species represented by 1848 individuals (Fisher and van Noort in prep.). This may be a consequence of the inventory having been carried out along a river course in the dry season, when there is a concentration effect in moist refugia (Janzen 1973b). However, this concentration effect should equally affect all the hymenopteran families, and the comparatively high ichneumonid proportion may be more feasibly attributed to high levels of parasitism by a few species of a common host in this habitat. Five species accounted for 71% of the ichneumonid abundance and 23% of the total hymenopteran abundance (van Noort, unpub.).

The lack of an evident elevational effect on ichneumonid species richness and abundance can probably be ascribed to homogeneity of the habitat across the limited altitudinal range on Monts Doudou (Sosef, this volume). Altitudinal gradients of species richness are well correlated with energy (temperature) (Rohde 1992; Rahbek 1995). Although there is climatic disparity across the sampled elevational range (Goodman, this volume) the re-

corded temperature gradient from 110 to 625 m (22.0–20.1°C daily minimum average and 28.2–24.9°C daily maximum average) is probably not sufficient to affect ichneumonid species richness. The high species turnover across elevation is likely to be a function of under sampling. The species-accumulationcurves show that none of the elevations were sufficiently sampled; with the result that further sampling may increase the number of shared species between elevations.

LITERATURE CITED

ARNETT, R. H. 1985. American insects: a handbook of the insects of America north of Mexico. Van Nostrand Reinhold Company, New York. 850 pp.

BASSET, Y., H. P. ABERLENC, H. BARRIOS, G. CURLETTI, J. M. BÉRENGER, J. P. VESCO, P. CAUSSE, A. HAUG, A. S. HENNION, L. LESOBRE, F. MARQUÈS, AND R. O'MEARA. 2001. Stratification and diel activity of arthropods in a lowland rain forest in Gabon. Biol. J. Linn. Soc. 72:585–607.

BOULINIER, T., J. D. NICHOLS, J. R. SAUER, J. E. HINES, AND K. H. POLLOCK. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79:1018–1028.

CHAZDON, R. L., R. K. COLWELL, J. S. DENSLOW, AND M. R. GUARIGUATA. 1998. Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forest of NE Costa Rica. Pp. 285–309 in Forest biodiversity research, monitoring and modelling: conceptual background and Old World case studies, F. Dallmeier and J. A. Comiskey, eds. Parthenon Publishing, Paris.

COE, M., N. MCWILLIAM, G. STONE, AND M. PACKER, eds. 1999. Mkomazi: the ecology, biodiversity and conservation of a Tanzanian savanna. Royal Geographical Society (with The Institute of British Geographers), London. 608 pp.

COLWELL, R. K. 1997. EstimateS: Statistical estimation of species richness and shared species from samples. Version 5.1. User's Guide and application published at: http://viceroy.eeb.uconn.edu/estimates.

ERWIN, T. 1982. Tropical forests: their richness in Coleoptera and other arthropod species. Coleopt. Bull. 36:74–75.

FISHER, B. L. 1999. Improving inventory efficiency: a case study of leaf-litter ant diversity in Madagascar. Ecol. Applic. 9:714–731.

GASTON, K. J. 1991. The magnitude of global insect species richness. Cons. Biol. 5:283–296.

———. 1993. Spatial patterns in the description and richness of the Hymenoptera. Pp. 277–293 in Hymenoptera and biodiversity, J. Lasalle and I. D. Gauld, eds. CAB International, Wallingford. 348 pp.

GASTON, K. J., I. D. GAULD, AND P. HANSON. 1996. The size and composition of the hymenopteran fauna of Costa Rica. J. Biogeog. 23:105–113.

GAULD, I. D. 1986. Latitudinal gradients in ichneumonid species-richness in Australia. Ecol. Ent. 11:155–161.

———. 1991. The Ichneumonidae of Costa Rica, 1. Introductions, keys to subfamilies, and keys to the species of the lower pimpliform subfamilies Rhyssinae, Pimplinae, Poemeniinae, Acaenitinae and Cylloceriinae. Mem. Amer. Ent. Inst. 47:1–577.

GAULD, I. D. AND K. J. GASTON. 1995. The Costa Rican Hymenoptera fauna. Pp. 13–19 in The Hymenoptera of Costa Rica, P. Hanson and I. D. Gauld, eds. Oxford University Press, Oxford.

GAULD, I. D. AND D. H. JANZEN. 1994. The classification, evolution and biology of the Costa Rican species of *Cryptophion* (Hymenoptera: Ichneumonidae). Zool. J. Linn. Soc. 110:297–324.

GAULD, I. D. AND P. A. MITCHELL. 1978. The taxonomy, distribution and host preferences of African parasitic wasps of the subfamily Ophioninae (Hymenoptera: Ichneumonidae). Commonwealth Agricultural Bureau, Slough. 287 pp.

GRISSELL, E. E. 1999. Hymenopteran biodiversity: some alien notions. Amer. Ent. 45:235–244.

GUPTA, S. AND V. GUPTA. 1983. Ichneumonologia Orientalis, 9. The tribe Gabuniini (Hymenoptera: Ichneumonidae). Orient. Insects Monog. 10:1–313.

GOTELLI, N. J. AND R. K. COLWELL. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4:379–391.

HAMMOND, P. M. 1992. Species inventory. Pp. 17–39 *in* Global Biodiversity, Status of the Earth's Living Resources, B. Groombridge, ed. Chapman and Hall, London. 585 pp.

HANSON, P. AND I. D. GAULD, eds. 1995. The Hymenoptera of Costa Rica. Oxford University Press, Oxford. 893 pp.

HEINRICH, G. H. 1968. Synopsis and Reclassification of the Ichneumoninae Stenopneusticae of Africa South of the Sahara (Hymenoptera). Farmington State College Press 4:695–941.

HESPENHEIDE, H. A. 1979. Are there fewer parasitoids in the tropics? Amer. Natur. 113:766–769.

JANZEN, D. H. 1973a. Sweep samples of tropical foliage insects: description of study sites, with data on species abundances and size distributions. Ecology 54:659–686.

———. 1973b. Sweep samples of tropical foliage insects: effects of seasons, vegetation types, elevation, time of day, and insularity. Ecology 54:687–708.

———. 1981. The peak in North American ichneumonid richness lies between 38° and 42°N. Ecology 62:532–537.

JANZEN, D. H. AND C. M. POND. 1975. A comparison, by sweep sampling, of the arthropod fauna of secondary vegetation in Michigan, England and Costa Rica. Trans. R. Ent. Soc. Lond. 127:33–50.

KOUKI, J. P. NIEMELÄ AND M. VIITASAARI. 1994. Reversed latitudinal gradient in species richness of sawflies (Hymenoptera, Symphyta). Ann. Zool. Fenn. 31:83–88.

LASALLE, J. AND I. D. GAULD, eds. 1993. Hymenoptera and biodiversity. CAB International, Wallingford. 348 pp.

LONGINO, J. T. AND R. K. COLWELL. 1997. Biodiversity assessment using structured inventory: capturing the ant fauna of a tropical rain forest. Ecol. Applic. 7:1263–1277.

MICHENER, C. D. 1979. Biogeography of the bees. Ann. Miss. Bot. Gard. 66:277–347.

MORRISON, G., M. AUERBACH, AND E. D. MCCOY. 1978. Anomalous diversity of tropical parasitoids: a general phenomenon? Amer. Natur. 114:303–307.

MAGURRAN, A. E. 1988. Ecological diversity and its measurement. Croom Helm, London. 179 pp.

NADKARNI, N. M. 1994. Diversity of species and interactions in the upper tree canopy of forest ecosystems. Amer. Zool. 34:70–78.

NOYES, J. S. 1989a. A study of five methods of sampling Hymenoptera (Insecta) in a tropical rain forest, with special reference to the Parasitica. J. Nat. Hist. 23:285–298.

———. 1989b. The diversity of Hymenoptera in the tropics with special reference to Parasitica in Sulawesi. Ecol. Ent. 14:197–207.

OWEN, D. F. AND J. OWEN. 1974. Species diversity in temperate and tropical Ichneumonidae. Nature 249:583–584.

OWEN, J., H. TOWNES, AND M. TOWNES. 1981. Species diversity of Ichneumonidae and Serphidae (Hymenoptera) in an English suburban garden. Biol. J. Linn. Soc. 16:315–336.

RAHBEK, C. 1995. The elevational gradient of species richness: a uniform pattern? Ecography 18:200–205.

RATHCKE, B. J. AND P. W. PRICE. 1976. Anomalous diversity of tropical ichneumonid parasitoids: a predation hypothesis. Amer. Natur. 110:889–893.

ROBERTSON, H. G. 1999. Ants (Hymenoptera: Formicidae) of Mkomazi. Pp. 321–336 *in* Mkomazi: the ecology, biodiversity and conservation of a Tanzanian Savanna, M. J. Coe, N. C. McWilliam, G. N. Stone, and M. Packer, eds. Royal Geographical Society (with The Institute of British Geographers), London. 608 pp.

ROHDE, K. 1992. Latitudinal gradients in species diversity: the search for the primary cause. Oikos 65:514–527.

SAWONIEWICZ, J. 1979. The effect of scrub layer on the occurrence of the Ichneumonidae (Hymenoptera) in pine stands on different sites. Mem. Zool. 30:89–130.

————. 1986. Structure of Ichneumonidae (Hymenoptera) communities in urban green areas of Warsaw. Mem. Zool. 41:255–271.

SEGADE, C., P. ROS-FARRÉ A. ALGARRA, D. VENTURA, AND J. PUJADE-VILLAR. 1997. Estudio comparativo de las capturas realizadas con trampa Malaise en Andorra con especial atención a los Himenópteros (Hymenoptera). Zapateri Revta. Aragon. Ent. 7:71–82.

STORK, N. E. 1991. The composition of the arthropod fauna of Bornean lowland rain forest trees. J. Trop. Ecol. 7:161–180.

TOWNES, H. 1969. The genera of Ichneumonidae, Part 1. Mem. Amer. Ent. Inst. 11:1–300.

————. 1972. A light-weight Malaise trap. Ent. News 83:239–247.

TOWNES, H. AND M. TOWNES. 1973. A catalogue and reclassification of the Ethiopian Ichneumonidae. Mem. Amer. Ent. Inst. 19:1–416.

VAN NOORT, S. AND S. G. COMPTON. 1999. Fig wasps (Agaonidae, Hymenoptera) and fig trees (Moraceae) of Mkomazi. Pp. 299–320 in Mkomazi: the ecology, biodiversity and conservation of a Tanzanian Savanna, M. J. Coe, N. C. McWilliam, G. N. Stone, and M. Packer, eds. Royal Geographical Society (with The Institute of British Geographers), London. 608 pp.

VAN NOORT, S., G. L. PRINSLOO, AND S. G. COMPTON. 2000. Hymenoptera excluding Apoidea (Apiformes) and Formicidae (Insecta). Pp. 289–364 in Dâures—biodiversity of the Brandberg Massif, Namibia, A. H. Kirk-Spriggs, and E. Marais, eds. Cimbebasia Memoir 9, National Museum of Namibia, Windhoek. 389 pp.

WHITE, F. 1983. The vegetation of Africa. A descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco. Paris.

WILSON, E. O. 1992. The diversity of life. Belknap Press, Cambridge, Massachusetts. 424 pp.

WOLDA, H. 1979. Abundance and diversity of Homoptera in the canopy of a tropical forest. Ecol. Ent. 4:181–190.

YU, D. S. 1998. Interactive Catalogue of World Ichneumonidae 1998. CD-ROM. Taxapad. Vancouver, Canada.

Fig Wasp (Hymenoptera: Chalcidoidea: Agaonidae, Pteromalidae, Eurytomidae and Ormyridae) and *Ficus* (Moraceae) Species Richness and Biogeography of Monts Doudou in Southwestern Gabon

Simon van Noort

Natural History Division, South African Museum (Iziko Museums of Cape Town),
P.O. Box 61, Cape Town, 8000, South Africa
email: svannoort@iziko.org.za

Thirty species of Chalcidoidea were reared from figs of three *Ficus* species (*F. sansibarica macrosperma*, *F. louisii*, and *F. elasticoides*) that were sampled on Monts Doudou, of which 28 are new records for the country, more than doubling the number of species previously known from Gabon, all of which were recorded from the vicinity of Makokou. Even though the majority of the fig wasp species sampled on Monts Doudou are currently only known from Gabon, their host fig tree distribution suggests that they will be more widespread through the Congo basin or even further afield. Of the 105 Afrotropical fig tree species, 47 are recorded from, or predicted to occur, in Gabon, illustrating the rich representation of *Ficus* species present in the country. These fig tree species are listed, together with the known fig wasps associated with each host tree. Based on current data, a conservative species richness of 225 fig wasps is associated with *Ficus* species in Gabon. The expected species richness, however, is likely to be closer to 400–500 species. Twenty to thirty-five fig tree species are predicted to occur on Monts Doudou, which from a *Ficus* perspective does not have sufficient elevation to support elements of Pleistocene refugia. The *Ficus* species predicted to occur on Monts Doudou are expected to have an associated fig wasp faunal richness of around 200–350 species.

RÉSUMÉ

Trente espèces de Chalcidoidea vivant sur trois espèces de figuiers (*Ficus sansibarica macrosperma*, *F. louisii* et *F. elasticoides*) ont été inventoriées au Mont Doudou; 28 de ces espèces sont nouvellement découvertes doublant le nombre d'espèces connues au Gabon. Ces espèces ont seulement été récoltées aux alentours de Makokou. Même si, aujourd'hui, la majorité des guêpes de figuiers récoltées au Mont Doudou sont seulement connues du Gabon, la large distribution des figuiers suggère que ces guêpes pourraient également être présentes jusqu'au bassin du Congo, voire plus loin.

Sur les 105 figuiers afrotropicaux, 47 sont connus ou supposés être présents au Gabon, illustrant une riche représentation d'espèces de figuiers dans le pays. Ces espèces de figuiers sont ici listées avec les guêpes qui leur sont associées. A partir des données actuelles, la diversité minimale de guêpes associées aux figuiers du Gabon devrait être de 225 espèces, mais le nombre pourrait atteindre 400 à 500 espèces. Vingt à trente-cinq espèces de figuiers devraient se trouver au Mont Doudou qui, par la perspective des *Ficus*, n'a pas une élévation suffisante pour supporter des éléments de refuges du Pléistocène. Les

espèces de *Ficus* qui sont supposées se trouver au Mont Doudou devraient présenter environ 200 à 350 espèces de guêpes de figuiers associées.

INTRODUCTION

The relationship between pollinating fig wasps (Chalcidoidea, Agaonidae) and their host fig trees (*Ficus*, Moraceae) is a classic example of an obligate mutualism, where neither partner can reproduce without the other, the wasp providing a pollination service and the fig tree in turn providing a breeding site for the pollinating wasp's progeny (Galil 1977; Janzen 1979). Besides the pollinator, each fig tree species has a diverse assemblage of non-pollinating fig wasps associated with it. The non-pollinating wasps are either phytophagous, galling the ovules as do the pollinators, or parasitoids of the gall formers (Compton and van Noort 1992; West and Herre 1994; West et al. 1996; Kerdelhué and Rasplus 1996a, 1996b). The mutualism between pollinating fig wasps and fig trees is usually a one-to-one relationship (Ramirez 1970; Wiebes 1979a; Wiebes and Compton 1990; Rasplus 1996) with each fig wasp species associated with a particular host fig tree species, of which there are approximately 750 worldwide (Berg 1989). There are, however, a few exceptions to this rule. A number of cases have been documented where two pollinator species are associated with a single host species (Compton et al. 1991; Michaloud et al. 1985; Michaloud et al. 1996; Berg and Wiebes 1992). Non-pollinating wasps appear to be almost as host-specific as the pollinators (Ulenberg 1985; van Noort 1994c).

In contrast to Bouček's (1988) classification, in which fig wasps were united under the single family Agaonidae, recent molecular investigations have shown that the Agaonidae is paraphyletic. Three of the constituent subfamilies of non-pollinating fig wasps (Sycoecinae, Otitesellinae, and Sycoryctinae) were reassigned to the Pteromalidae, leaving the pollinating fig wasps in the Agaonidae (Rasplus et al. 1998). The true taxonomic affinities of the Sycophaginae and Epichrysomallinae remain undecided, but they do not belong in the Agaonidae. In addition, there are representatives of the Eurytomidae and Ormyridae that are also associated with figs in Africa.

Fig wasps are circumtropical in distribution, with about 230 described species of an estimated 700–1000 species in the Afrotropical region (van Noort and Rasplus 1997; van Noort unpublished). Fig wasps are exclusively associated with figs and since *Ficus* species richness is centered in the tropics, Gabon has a rich representation of species, with a total of 47 fig tree species recorded from, or predicted to, occur in the country (Berg et al. 1984). This high diversity is in line with other tropical African countries: Cameroon (58 species) (Berg et al. 1985), Tanzania (39), Kenya (34) and Uganda (43) (Berg and Hijman 1989). Given the pan-tropical distribution of *Ficus*, it is predictable that temperate countries such as South Africa support a lower diversity (22 species) (Berg 1990).

Local *Ficus* species richness is extremely high in Gabon. In the Lopé Reserve in central Gabon, which lies approximately 250 km northwest of Monts Doudou, at least 18 species of *Ficus* are present (White and Abernethy 1997). Thirty-four species have been recorded from the vicinity of Makokou in northeastern Gabon (Berg et al. 1984), with 28 hemi-epiphytic *Ficus* species recorded around the Institut de Recherches en Ecologie Tropicale station at M'Passa, situated 10 km south of Makokou (Nieder et al. 2001). Very few assessments of local fig wasp species richness have been conducted in Africa. During an ecological inventory survey of the fauna and flora occurring in Mkomazi Game Reserve in northeastern Tanzania (Coe et al. 1999), an assessment of fig tree and fig wasp species richness of this semi-arid east African savanna region was carried out (van Noort and

Compton 1999). Eighty-five species of fig wasp, of an expected species richness of 170, were reared from nine host fig tree species. For comparative purposes, van Noort and Compton (1999) demarcated an area in Kwazulu-Natal (South Africa) that was similar in size to Mkomazi Game Reserve, where 90 fig wasp species of a potential 117 species were recorded from 12 host fig tree species.

Research on fig trees and fig wasps in Gabon has centered on ecological and evolutionary investigations. These were conducted on *Ficus* species and their associated fig wasp assemblages in the vicinity of the Institut de Recherches en Ecologie Tropicale station at M'Passa, situated 10 km south of Makokou in northeastern Gabon (Gautier-Hion and Michaloud 1989; Michaloud 1982; 1988; Michaloud et al. 1985; Michaloud et al. 1996; Nieder et al. 2001). A number of fig wasp species have been described from collections made by Georges Michaloud and others in the vicinity of Makokou (Wiebes 1979b, 1979c, 1986, 1988, 1989; Michaloud et al. 1985; van Noort 1993a, 1993b, 1994a, 1994b, 1994c). Prior to the collections made on Monts Doudou only 26 described species of fig wasp had been recorded from Gabon (Berg and Wiebes 1992; van Noort, unpublished, see also web site at: http://www.museums.org.za/sam/collect/life/ento/simon/figwasp.htm), which is simply a function of a lack of collecting fig wasps in the region. Within Gabon all these species are only known from the vicinity of Makokou and for a number of them Makokou is the type (and currently only known) locality.

In this paper the sampled species richness of fig wasps on Monts Doudou is reported on and a summary of expected *Ficus* and fig wasp species richness is provided for Gabon and Monts Doudou. The biogeographical affinities of Gabon's fig wasps and fig trees are discussed.

MATERIALS AND METHODS

Study site
Monts Doudou is situated in Province Ogoové-Maritime in southwestern Gabon and straddles two reserves: Réserve de la Moukalaba-Dougoua and Réserve des Monts Doudou. Fig wasps were collected at three localities: 2°17.00'S, 10°29.83'E (110 m); 2°12.36'S, 10°25.11'E (110 m); 2°13.63'S, 10°23.67'E (660 m). The habitat is defined as coastal lowland rain forest (White 1983).

Sampling methods
Fig wasps were collected on an opportunistic basis. The majority of fig trees that were located were stranglers in other tree species, and the fig crops were located in the forest canopy 30–50 m above the ground. Accessing the forest canopy could not be accommodated in the logistics of the survey and sampling of fig crops relied on locating figs that had been knocked to the forest floor. This was facilitated by the activities of primates feeding on ripe figs and by adverse weather conditions. One of the collections was made possible through a severe thunderstorm that knocked many figs to the forest floor. Figs were placed in a plastic jar with a gauze lid. Fig wasps that emerged were aspirated and preserved in 96% ethanol. After a couple of days the figs were split open and any fig wasps remaining within the fig cavity were extracted and preserved.

Identification and analyses
Specimens were identified to family and subfamily, and where possible, to species. However, the majority of the species are undescribed and hence were sorted to

TABLE 1. Fig wasps reared from the *Ficus* species that were sampled on Monts Doudou. Family placement of the Epichrysomallinae is currently unresolved.

Ficus sp.	Agaonidae	Pteromalidae Sycoecinae	Pteromalidae Otitesellinae	Pteromalidae Sycorytinae	Family ? Epichrysomallinae	Eurytomidae	Ormyridae
F. sansibarica macrosperma	*Courtella armata*	*Seres a. armipes*	*Otitesella* sp. 1	*Sycoscapteridea* sp. *Sycoryctes* sp. 1 *Sycoryctes* sp. 2 *Sycoryctes* sp. 3 *Watshamiella* sp. 1 *Watshamiella* sp. 2	*Camarothorax* sp. 1	*Sycophila* sp. 1 *Sycophila* sp. 2 *Sycophila* sp. 3	
F. louisii	*Paragaon josephi*	*Crossogaster* sp.	*Otitesella* sp. 2 *Otitesella* sp. 3	*Sycoryctes* sp. 4 *Sycoryctes* sp. 5	*Camarothorax* sp. 2 *Camarothorax* sp. 3		*Ormyrus* sp.
F. elasticoides	*Elisabethiella articulata*		*Otitesella* sp. 4 *Philosycus* sp.	*Sycoryctes* sp. 6 *Sycoryctes* sp. 7 *Watshamiella* sp. 3	*Camarothorax* sp. 4	*Sycophila* sp. 4	

morpho-species. Owing to the limited number of samples it was not possible to carry out species richness analyses or to assess the effect of elevation on patterns of species richness. The collected material is deposited in the South African Museum, Cape Town. Representative specimens will be returned to Libreville, Gabon.

RESULTS

Thirty fig wasp species, representing 12 genera and seven higher taxa at family or subfamily level, were reared from three species of fig tree: *Ficus sansibarica macrosperma* (Mildbr. and Burret) C. C. Berg; *Ficus louisii* Bout. and Leon; and *Ficus elasticoides* De Wild. The fig wasp faunal assemblages reared from these three host fig tree species are listed in Table 1. The forty-seven *Ficus* species that occur, or are predicted to occur, in Gabon, currently have a predicted associated fig wasp faunal assemblage of 225 species (Appendix A).

DISCUSSION

Species richness

Monts Doudou is only the second locality in Gabon that has been sampled for fig wasps. This survey added a further 28 species to the previously recorded total of 26 described species from the vicinity of Makokou in northeastern Gabon. Based on this total of 54 species in conjunction with the fig wasp species richness that has been recorded elsewhere in Africa from those *Ficus* species that occur in Gabon, at least 225 species of fig wasp are predicted to occur in this central African country (Appendix A). Seven *Ficus* species that occur, or are predicted to occur, in Gabon have never had their associated fig wasp faunas reared, and as such their pollinators and non-pollinating fig wasp faunas are unknown (Appendix A). In addition, the majority of the 47 *Ficus* species that occur in Gabon have not had their full assemblage of fig wasps reared from them any-

220

where within their distributional range in Africa. As such the estimate of 225 fig wasp species associated with Gabon's fig species is extremely conservative. As with many invertebrate taxa, the lack of alpha-level taxonomic and biogeographical knowledge of fig wasps is a function of insufficient sampling. The paucity of distributional information in Gabon is indicative of most of the rest of Africa, where there are still vast areas where no collecting of fig wasps has been undertaken. Collecting of fig wasps is hindered by the need to rear specimens from their host figs, a procedure which is constrained by the ecology of the mutualism. Fig crops are produced randomly throughout the year and individual trees produce crops at different times to each other, both essential traits to ensure the continued cycling of the mutualism (Bronstein, 1992). Because of this, most of the fig trees that are located during field surveys either have no figs or have figs at the wrong stage of development for rearing of fig wasps. On average only one out of every 30 trees has a fig crop at the right stage of development (pers. observ.). Furthermore, not every fig wasp species associated with a particular fig tree species is reared from every sample of figs. There are two reasons for this. First, not every fig crop borne by the tree has all the possible fig wasp species present, due to either the cycling of the mutualism, where the full fig wasp species compliment does not locate every potential fig crop, or alternatively some fig wasp species may be absent from the local geographical area. Second, it is not practical to sample every fig in a particular crop. Since not all the fig wasp species associated with a particular fig crop will be breeding in every fig, rare species may be missed. To fully sample the fig wasp species assemblage associated with a fig tree species may require up to 23 collections from different trees of that species in a particular geographical area (Compton and Hawkins 1992; Compton et al. 1994; West et al. 1996). This is illustrated by an example from the New World where a single crop of *F. aurea* in Florida (USA) produced four species of fig wasp, a sample of 12 crops over time from the same tree produced seven species, and a sample of 60 crops from 23 different trees produced a total of nine species (Bronstein and Hossaert-McKey, 1996). Thus, the single samples collected from Monts Doudou *Ficus* are insufficient to assess fig wasp species richness associated with these host species.

The total of three *Ficus* species recorded for Monts Doudou is likely to be a small fraction of the total number of species occurring there. Based on assessments of local *Ficus* species richness in other areas of Gabon, such as a richness of at least 18 species of *Ficus* in the Lopé Reserve (White and Abernethy 1997) and 34 species within the vicinity of Makokou (Berg et al. 1984), around twenty to thirty-five fig tree species are predicted to occur on Monts Doudou, with an estimated associated fig wasp faunal richness of roughly 200–350 species. The estimation of fig wasp richness is based on known species richness of fig wasp assemblages associated with well-sampled fig tree species and the actual richness may be as much as three times greater, since up to 31 species of fig wasp have been recorded as being associated with a single *Ficus* species (van Noort and Compton 1999; J. Y. Rasplus pers. comm.). This, however, is tempered by the fact that the degree of host-specificity has not been determined for all of the non-pollinating groups of fig wasps, although the groups that have been revised so far show a high degree of specificity (Ulenberg 1985; van Noort 1994c). As such, a hypothesis that 10 wasp species are specific to each fig tree species may be a more realistic interpretation, albeit an extremely conservative one.

Biogeography

Ficus endemism is low in Gabon with no species restricted to the country. However, three species are sub-endemic with a distribution encompassing Gabon and Cameroon: *F.*

abscondita C. C. Berg, *F. subsagittifolia* C. C. Berg, and *F. cyathistipula pringsheimiana* (Braun and K. Shum.) C. C. Berg (Berg et al. 1984). The nominate subspecies of *F. cyathistipula* Warberg has a wider distribution from Ivory Coast to Angola, N. Zambia, Kenya and Tanzania, but has a different species of pollinating wasp and a different assemblage of non-pollinating wasps, suggesting that these two subspecific taxa are distinct at species level. A further six Gabon species are restricted to the central African region. Eighteen of the Gabon species (plus a further two species that are predicted to occur in Gabon) are distributed through central and west Africa. The remaining Gabon species enjoy a more widespread distribution extending into east and southern Africa. Given this fairly widespread distribution of the *Ficus* species that occur in Gabon and the fact that all three of the sub-endemic Gabon species are lowland forest taxa, Monts Doudou is unlikely to have any endemic species. From a biogeographical perspective Monts Doudou does not have a high enough altitude to support (sub)montane *Ficus* species, and although the mountain has been postulated to be a Pleistocene refuge based on the presence of a number of *Begonia* species that occur towards the peak (Sosef 1994), the presence of *F. louisii*, a lowland forest species, on the peak (660 m) of Monts Doudou suggests that this elevation is within the climatic tolerance of widespread lowland *Ficus* species. Species with distributions conforming to Pleistocene refugia, such as *Ficus oreodryadum* Mildbr., which is predicted to occur in Gabon and is distributed from Uganda, Rwanda, Burundi to Cameroon, SE Nigeria and Fernando Po, are restricted to montane and submontane forest between 1300–2500 m (Berg et al. 1984), and the only likely locality that this species may be present in Gabon is on Mont Cristal. Given the obligate mutualism between fig wasps and fig trees, the above discussion concerning endemism and Pleistocene refugia will hold for fig wasps as well. However, this assumption needs to be treated with caution as not all fig wasp species are distributed throughout the range of their host fig tree species (Compton et al. 1994).

Biogeographical affinities of Monts Doudou fig wasps could only be ascertained for the four described species that were collected. *Courtella armata*, the pollinator of *Ficus sansibarica*, has been reared from both subspecies of this host, the nominate subspecies and *F. sansibarica macrosperma*, in Ivory Coast, Nigeria, Cameroon, Zambia, Zimbabwe and South Africa (Wiebes 1986; Berg and Wiebes 1992; van Noort, unpub.). This is the first published record of this species from Gabon. *Ficus sansibarica* is a widespread Afrotropical species distributed from eastern South Africa and northern Angola north to Kenya and Uganda and west to Guinea-Bissau (Berg and Wiebes 1992), and the pollinator would be expected to exhibit the same distributional pattern. *Seres armipes*, a non-pollinating sycoecine fig wasp reared from *F. s. macrosperma* on Monts Doudou, was described from specimens reared from *Ficus ovata,* which is pollinated by *Courtella hamifera* Kieffer, and has been recorded from Ivory Coast, Cameroon and Uganda associated with *Ficus ovata*. *Seres armipes* has previously been recorded from *Ficus sansibarica macrosperma* in Ivory Coast and Zambia (van Noort 1993a), but this is the first record of this species from Gabon. *Paragaon josephi*, the pollinator of *Ficus louisii*, is only known from Gabon having been described from specimens reared from *F. louisii* at Makokou (Wiebes 1986). However, the species is likely to be more widespread as *F. louisii* is a central and west African species recorded from Democratic Republic of the Congo, Gabon, Cameroon and Guinea (Berg and Wiebes 1992). DNA has been successfully extracted from the samples of *Paragaon josephi* Wiebes collected on Monts Doudou as part of an investigation into the phylogeny and evolution of fig-pollinating wasps at generic level (J. M. Cook, V. Bull, and C. Lopez Vaamonde in prep.). The *Crossogaster* species that was reared

from this fig tree is undescribed. This sycoecine genus was recently revised (van Noort 1994a) and the species associated with *F. louisii* is distinct from the 16 described *Crossogaster* species. *Elisabethiella articulata*, the pollinator of *F. elasticoides*, has previously been reared from this host species in Gabon (Makokou) (Wiebes 1986), and has also been collected in a Berlese trap (Equatorial Guinea) and at light (Ivory Coast) (Berg and Wiebes 1992). *Ficus elasticoides* is a lowland rain forest species distributed from Angola to Cameroon and is also present in Ivory Coast (Berg and Wiebes 1992). The remainder of the fig wasps that were reared from the 3 sampled fig tree species are likely to be undescribed species, but this is difficult to ascertain without the revision of the groups in question having been completed (van Noort, in prep.).

In summary, the sampling of fig wasps during the survey of Monts Doudou was done on an opportunistic basis. Consequently, it is likely that many further species of *Ficus* still wait to be recorded, each with its own host-specific fig wasp fauna. In addition, the fig wasp species richness recorded from the three sampled fig tree species on Monts Doudou is currently an under-representation, given the limited sampling effort. For both these reasons, the results are a gross underestimation of fig wasp species richness in this locality. Nevertheless, indications are that Gabon supports a rich *Ficus* and fig wasp fauna, a factor that will likely hold for Monts Doudou as well.

APPENDIX A

Checklist of fig tree species recorded from Gabon or predicted to occur there (after Berg et al. 1984; nomenclature updated), and including a list of the predicted associated fig wasp fauna for each *Ficus* species based on collections made elsewhere in Africa. The fig wasp species that have been recorded (both previously and during this survey) from Gabon are indicated in bold text. Habitat associations of fig tree species are after Berg and Wiebes (1992). Distributions of the fig tree species are summarised as Southern Africa (S); East Africa (E); Central Africa (C) and West Africa (W).

FICUS OF GABON

SYCIDIUM (subgenus)
SYCIDIUM (section)
1. *F. exasperata* Vahl (S, E, C, W AFRICA) Forest up to 1800 m
    Kradibia gestroi afrum (Wiebes)
    Sycoscapteridea longipalpus (Joseph)
    Philotrypesis quadrisetosa (Westwood)
    Sycoryctes sp.

2a. *F. asperifolia* Miq. (E, C, W AFRICA) Wet and dry forest along streams
   Kradibia gestroi afrum (Wiebes)

2b. *F. asperifolia* Miq. ("variety" *urceolaris*)
   Kradibia hilli Wiebes

SYCOMORUS (subgenus)
3. *F. mucuso* Ficalho (E, C, W AFRICA) Forest
   Ceratosolen arabicus Mayr
   Ceratosolen galili Wiebes
   Apocrypta crypta Ulenberg
   Apocryptophagus sp A
   Apocryptophagus sp. B

4. *F. sur* Forsk. (S, E, C, W AFRICA) Woodland and forest
   Ceratosolen silvestrianus Grandi
   Ceratosolen flabellatus Grandi
   Sycophaga cyclostigma Wiebes
   Sycophaga silvestrii Grandi
   Apocryptophagus sp. A
   Apocryptophagus sp. B
   Apocryptophagus sp. C
   Apocryptophagus sp. D
   Apocrypta guineensis Grandi
   Apocrypta sp. B
   Sycoscapter nigrum Risbec
   Sycoscapter sp. B
   Watshamiella sp. A
   Watshamiella sp. B
   Watshamiella sp. C
   Camarothorax sp.
   Sycophila sp.
   Acophila sp.

5. *F. vogeliana* (Miq.) Miq. (E, C, W AFRICA) Riverine and swamp forest
   Ceratosolen acutatus Grandi
   Sycophaga sp.
   Apocryptophagus sp. A
   Apocryptophagus sp. B
   Apocrypta sp.
   Watshamiella sp.

PHARMACOSYCEA (subgenus)
OREOSYCEA (section)
6. *F. variifolia* Warb. (E, C, W AFRICA) Wet and dry forest up to 1300 m
   Dolichoris flabellata Wiebes

7. *F. dicranostyla* Mildbr. (E, C, W AFRICA) Savanna woodland up to 1500 m

Dolichoris flabellata Wiebes

UROSTIGMA (subgenus)
UROSTIGMA (section)
8. *F. ingens* (Miq.) Miq. (S, E, C, W AFRICA) (Predicted to occur in Gabon) Woodland
    Platyscapa soraria Wiebes
    Otitesella rotunda van Noort
    Otitesella longicauda van Noort
    Sycoryctes sp. A
    Sycoryctes sp. B
    Sycoryctes sp. C
    Philotrypesis sp.

GALOGLYCHIA (section)
GALOGLYCHIA (subsection)
 9. *F. lutea* Vahl (S, E, C, W AFRICA) Forest up to 1800 m
    Allotriozoon heterandromorphum Grandi
    Philocaenus silvestrii (Grandi)
    Sycoryctes sp. A
    Sycoryctes sp. B
    Sycoscapter sp.
    Watshamiella sp.
    Philotrypesis selenetica Grandi
    Philotrypesis sp.
    Otitesella africana Grandi
    Otitesella sp. B
    Camarothorax sp. A
    Camarothorax sp. B
    Sycophila sp. A
    Sycophila sp. B
    Sycophila sp. C
    Sycophila sp. D
    Sycophila sp. E

PLATYPHYLLAE (subsection)
10. *F. recurvata* De Wildeman (C, W AFRICA) Forest at low altitudes

11. *F. jansii* Boutique (C AFRICA) (Predicted to occur in Gabon) Forest up to 1500 m

12. *F. trichopoda* Baker (S, E, C, W AFRICA)
    Elisabethiella bergi Wiebes
    Crossogaster robertsoni van Noort
    Philocaenus hippopotomus van Noort
    Sycoryctes sp. A
    Sycoryctes sp. B
    Sycoscapter sp. A
    Sycoscapter sp. B
    Philotrypesis sp.

Otitesella sp.
Watshamiella sp A
Watshamiella sp. B
Camarothorax sp.

CHLAMYDODORAE (subsection)
13. *F. calyptrata* Vahl (= *F. mallotoides*) (C, W AFRICA) Forest up to 700 m
Elisabethiella pectinata (Joseph)

14. *F. amadiensis* De Wild (E, C AFRICA) (Predicted to occur in Gabon) Woodland up to
2100 m

15. *F. craterostoma* Mildbr. and Burret (S, E, C, W AFRICA) Forest up to 2100 m
Alfonsiella michaloudi Wiebes
Philocaenus liodontus (Wiebes)
Philocaenus insolitus van Noort
Sycoryctes sp.
Otitesella sp.

16. *F. linqua linqua* De Wild. and T. Durand (E, C, W AFRICA) Forest up to 1200 m
Alfonsiella michaloudi Wiebes
Philocaenus liodontus (Wiebes)

17. *F. natalensis leprieurii* (Miq.) C. C. Berg (C, W AFRICA) Forest, woodland up to
1200 m
Alfonsiella fimbriata Waterston
Philocaenus liodontus (Wiebes)

18. *F. thonningii* Bl. (S, E, C, W AFRICA) Wet and dry forest up to 2000 m
Elisabethiella stuckenbergi Grandi
Alfonsiella brongersmai Wiebes
Alfonsiella longiscapa Joseph
Philocaenus barbarus (Grandi)
Crossogaster odorans Wiebes
Philotrypesis parca Wiebes
Sycoscapter cornutus Wiebes
Sycoryctes remus Wiebes
Sycoryctes hirtus Wiebes
Watshamiella alata Wiebes
Watshamiella sp. A
Watshamiella sp. B
Otitesella tsamvi Wiebes
Otitesella sp. B
Camarothorax brevimucro Bouček
Camarothorax equicollis Bouček
Camarothorax longimucro Bouček
Sycotetra serricornis Bouček
Eurytoma ficusgallae Bouček

Ficomila curtivena Bouček
Ficomila gambiensis (Risbec)
Syceurytoma ficus Bouček
Sycophila flaviclava Bouček
Sycophila kestraneura (Masi)
Sycophila modesta Bouček
Sycophila naso Bouček
Sycophila punctum Bouček
Sycophila sessilis Bouček
Ormyrus flavipes Bouček
Ormyrus subconicus Bouček
Ormyrus watshami Bouček

19. *F. kamerunensis* Mildbr. and Burret (C, W AFRICA) Forest at low altitudes
    ***Alfonsiella fimbriata* Waterston**
    ***Philocaenus liodontus* (Wiebes)**

CRASSICOSTAE (subsection)
20. *F. elasticoides* De Wild. (C, W AFRICA) Forest at low altitudes
    ***Elisabethiella articulata* (Joseph)**
    ***Otitesella* sp. A**
    ***Philosycus* sp.**
    ***Sycoryctes* sp. A**
    ***Sycoryctes* sp. B**
    ***Watshamiella* sp.**
    ***Camarothorax* sp.**

21. *F. burretiana* Hutch. (C AFRICA) Forest at low altitudes
    ***Elisabethiella longiscapa* Wiebes**

22. *F. oreodryadum* Mildbr. (C, W AFRICA) (Predicted to occur in Gabon) (Sub)montane
    forest 1300–2500 m

23. *F. pseudomangifera* Hutch. (C, W AFRICA) Forest up to 1200 m
    ***Nigeriella letouzeyi* Wiebes**

24. *F. adolfi-friderici* Mildbr. (C, W AFRICA) Forest at low altitudes

25. *F. louisii* Boutique and J. Léonard (C, W AFRICA) Forest at low altitudes
    ***Paragaon josephi* Wiebes**
    ***Crossogaster* sp.**
    ***Otitesella* sp. A**
    ***Otitesella* sp. B**
    ***Sycoryctes* sp. A**
    ***Sycoryctes* sp. B**
    ***Camarothorax* sp. A**
    ***Camorothorax* sp. B**
    ***Sycophila* sp.**

***Ormyrus* sp.**

26. *F. leonensis* Hutch. (C, W AFRICA) (Predicted to occur in Gabon) Forest

CYATHISTIPULAE (subsection)
27. *F. conraui* Warb. (C, W AFRICA) Forest
    Agaon kiellandi Wiebes

28. *F. tesselata* Warb. (C, W AFRICA) Forest, often riverine, up to 1900 m
    Agaon taiense Wiebes
    Sycoecus bergi van Noort

29a. *F. ardisioides ardisioides* Warb. (C AFRICA) (Predicted to occur in Gabon) Forest at
    low altitudes

29b. *F. ardisioides camptoneura* (Mildbr.) C. C. Berg (C, W AFRICA) Forest at low
    altitudes
    Agaon megalopon Wiebes
    Philotrypesis sp.

30. *F. preussii* Warb. (C, W AFRICA) Forest up to 1200 m
    Agaon sp.

31. *F. abscondita* C. C. Berg (C AFRICA) Forest at low altitudes
    Agaon sp.

32a. *F. cyathistipula cyathistipula* Warb. (E, C, W AFRICA) Forest, often riverine up to
    1800 m
    ***Agaon fasciatum* Waterston**
    Sycoecus thaumastocnema Waterston

32b. *F. cyathistipula pringsheimiana* (Braun and K. Shum.) C. C. Berg (C AFRICA) Forest
    at low altitudes
    ***Agaon kiellandi* Wiebes**
    Sycoecus oculabulbus van Noort
    Sycoryctes sp.

33. *F. cyathistipuloides* De Wild. (C, W AFRICA) Forest at low altitudes
    Agaon obtusum Wiebes
    Sycoecus wiebesi van Noort
    Watshamiella sp. A
    Watshamiella sp. B
    Watshamiella sp. C
    Philotrypesis sp.

34. *F. densistipulata* De Wild. (C AFRICA) Forest up to 1250 m
    ***Agaon kiellandi* Wiebes**

35. *F. subcostata* De Wild. (C AFRICA) Forest at low altitudes

Agaon acutatum **Wiebes**

36. *F. barteri* Sprague (C, W AFRICA) Forest up to 1200 m
    Agaon paradoxum **Dalman**

37. *F. subsagittifolia* C. C. Berg (C AFRICA) Forest at low altitudes
    Agaon cicatriferens multum **Wiebes**
    Sycoecus wiebesi **van Noort**

38. *F. wildemaniana* De Wild. and T. Durand (C AFRICA) Forest up to 1100 m
    Agaon gabonense **Wiebes**

CAULOCARPAE (subsection)
39a. *F. ottoniifolia ottoniifolia* (Miq.) Miq. (C, W AFRICA) Open forest up to 1600 m
    Courtella camerunensis **(Wiebes)**
    Courtella gabonensis **Wiebes**

39b. *F. ottoniifolia lucanda* (Ficalho) C. C. Berg (C AFRICA) Wet to dry forest up to 1500 m
    Courtella scobinifera (Waterston)
    Philocaenus levis (Waterston)

40. *F. tremula kimuenzensis* (Warb) C. C. Berg (C, W AFRICA) Forest at low altitudes

41. *F. artocarpoides* Warb. (C, W AFRICA) Forest up to 1200 m
    Courtella penicula **(Wiebes)**
    Courtella hladikae **(Wiebes)**
    Seres longicalcar **van Noort**
    Crossogaster michaloudi **van Noort**
    Philocaenus rasplusi **van Noort**

42. *F. polita polita* Vahl (S, E, C, W AFRICA) Forest up to 1200 m
    Courtella bekiliensis (Risbec)
    Seres solweziensis van Noort
    Sycoryctes sp. A
    Sycoryctes sp. B
    Sycoscapter sp.
    Sycoscapteridea sp.
    Watshamiella sp.
    Philotrypesis sp.
    Otitesella sp.
    Camarothorax sp.
    Sycophila sp. A
    Sycophila sp. B

43. *F. sansibarica macrosperma* (Mildbr. and Burret) (C, W AFRICA) Forest and woodland up to 1200 m
    Courtella armata **(Wiebes)**
    Seres armipes **Waterston**

Seres solweziensis van Noort
Otitesella sp.
Sycoryctes sp. A
Sycoryctes sp. B
Sycoryctes sp. C
Sycoscapteridea sp.
Sycoscapter sp.
Watshamiella sp. A
Watshamiella sp. B
Camarothorax sp.
Sycophila sp. A
Sycophila sp. B
Sycophila sp. C

44. *F. dryepondtiana* De Wild. (C AFRICA) Forest at low altitudes
Courtella sylviae Wiebes

45. *F. umbellata* Vahl (C, W AFRICA) Forest and woodland at low altitudes
Courtella medleri (Wiebes)

46. *F. bubu* Warb. (S, E, C, W AFRICA) Forest and woodland up to 1200 m
Courtella michaloudi (Wiebes)
Seres wardi van Noort
Sycoryctes sp. A
Sycoryctes sp. B
Sycoryctes sp. C
Sycoryctes sp. D
Sycoryctes sp. E
Sycoryctes sp. F
Sycoscapter sp.
Sycoscapteridea sp.
Philotrypesis sp.
Watshamiella sp. A
Watshamiella sp. B
Otitesella sp.
Philosycus sp.
Camarothorax sp. A
Camarothorax sp. B
Camarothorax sp. C
Camarothorax sp. D
nr. *Camarothorax* sp.
Ficomila sp.
Sycophila sp. A
Sycophila sp. B
Sycophila sp. C
Sycophila sp. D
Sycophila sp. E
Sycophila sp. F

Sycophila sp. G
Sycophila sp. H
Ormyrus sp.

47. *F. ovata* Vahl (S, E, C, W AFRICA) Forest, often riverine and woodland up to 2100 m
Courtella hamifera Kieffer
Seres armipes Waterston
Seres solweziensis van Noort
Crossogaster ovata van Noort
Sycoryctes sp. A
Sycoryctes sp. B
Watshamiella sp.
Philotrypesis africana Grandi
Philotrypesis sp. B
Philosycus monstruosus (Grandi)
Otitesella sp.

LITERATURE CITED

BERG, C. C. 1989. Classification and distribution of *Ficus*. Experientia 45:605–611.
———. 1990. Annotated check-list of the *Ficus* species of the African floristic region, with special reference and a key to the taxa of southern Africa. Kirkia 13:253–291.
BERG, C. C. AND M. E. E. HIJMAN. 1989. Ficus. Chapter 11. Pp. 43–86 *in* Flora of Tropical East Africa, R. M. Polhill, ed. A. A. Balkema, Rotterdam.
BERG, C. C., M. E. E. HIJMAN AND J. C. A. WEERDENBURG. 1984. Moracées (incl. Cécropiacées). Flore du Gabon 26:1–276.
———. 1985. Moracées (incl. Cécropiacées). Flore du Cameroun 28:1–298.
BERG, C. C. AND J. T. WIEBES. 1992. African Fig Trees and Fig Wasps. K. ned. Akad. Wet., Verhandelingen Afdeling Natuurkunde, Tweede Reeks, Deel 89, Amsterdam. 298 pp.
BOUÈEK, Z. 1988. Australasian Chalcidoidea (Hymenoptera). A biosystematic revision of genera of fourteen families with a reclassification of species. C.A.B. International, Wallingford. 832 pp.
BRONSTEIN, J. L. 1992. Seed predators as mutualists: ecology and evolution of the fig/pollinator interaction. Pp. 1–44 *in* Insect-Plant Interactions Vol IV, E. Bernays, ed. CRC Press, London.
BRONSTEIN, J. L. AND M. HOSSAERT-MCKEY. 1996. Variation in reproductive success within a subtropical fig/pollinator mutualism. J. Biogeog. 23:433–466.
COE, M., N. MCWILLIAM, G. STONE, AND M. PACKER, eds. 1999. Mkomazi: the ecology, biodiversity and conservation of a Tanzanian savanna. Royal Geographical Society (with The Institute of British Geographers), London. 608 pp.
COMPTON, S. G. AND B. A. HAWKINS. 1992. Determinants of species richness in southern African fig wasp assemblages. Oecologia 91:68–74.
COMPTON, S. G., K. C. HOLTON, V. K. RASHBROOK, S. VAN NOORT, S. L. VINCENT, AND A. B. WARE. 1991. Studies of *Ceratosolen galili*, a non-pollinating agaonid fig wasp. Biotropica 23:188–194.
COMPTON, S. G. AND S. VAN NOORT. 1992. Southern African fig wasps (Hymenoptera: Chalcidoidea): resource utilization and host relationships. Proc. Kon. Ned. Akad. v. Wetensch. 95:423–435.
COMPTON, S. G., J. Y. RASPLUS, AND A. B. WARE. 1994. African fig wasp parasitoid communities. Pp. 343–368 *in* Parasitoid Community Ecology, B. A. Hawkins and W. Sheenan, eds. Oxford University Press, Oxford.
GALIL, J. 1977. Fig Biology. Endeavour 1:52–56.
GAUTIER-HION, A. AND G. MICHALOUD. 1989. Are figs always keystone resources for tropical frugivorous vertebrates? A test in Gabon. Ecology 70:1826–1833.
JANZEN, D. H. 1979. How to be a fig. A. Rev. Ecol. Syst. 10:13–51.
KERDELHUÉ, C. AND J. Y. RASPLUS. 1996a. Non-pollinating Afrotropical fig wasps affect the fig-pollinator mutualism in *Ficus* within the subgenus *Sycomorus*. Oikos 75:3–14.

———. 1996b. The evolution of dioecy among *Ficus* (Moraceae): an alternative hypothesis involving non-pollinating fig wasp pressure on the fig-pollinator mutualism. Oikos 77:163–166.

MICHALOUD, G. 1982. Figuiers tropicaux et pollinisation. Film, réalisation A. R. Devez, production Service du Film de Recherche Scientifique, Paris.

———. 1988. Aspects de la reproduction des figuiers monoïques en forêt équatoriale africaine. Thèse d'Université. Université de Montpellier II, France. 256 pp.

MICHALOUD, G., S. CARRIÈRE, AND M. KOBBI. 1996. Exceptions to the one:one relationship between African fig trees and their fig wasp pollinators: possible evolutionary scenarios. J. Biogeog. 23:513–520.

MICHALOUD, G., S. MICHALOUD-PELLETIER, J. T. WIEBES, AND C. C. BERG. 1985. The co-occurrence of two pollinating species of fig wasp and one species of fig. Proc. Kon. Ned. Akad. v. Wetensch. 88:93–119.

NIEDER, J., J. PROSPERI, AND G. MICHALOUD. 2001. Epiphytes and their contribution to canopy diversity. Plant Ecology 153:51–63.

RAMIREZ, W. B. 1970. Host specificity of fig wasps (Agaonidae). Evolution, N.Y. 24:680–691.

RASPLUS, J. Y. 1996. The one-to-one species specificity of the *Ficus*-Agaoninae mutualism: how casual? Pp. 639–649 *in* The biodiversity of African plants, L. J. G. van der Maesen, X. M. van den Burgt and J. M. van den Medenbrah de Rooy, eds. Kluwer Academic Publishers, Dordrecht.

RASPLUS, J. Y., C. KERDELHUÉ, I. LE CLAINCHE, AND G. MONDOR. 1998. Molecular phylogeny of fig wasps. Agaonidae are not monophyletic. C. R. Acad. Sci. Paris, Sciences de la vie 321:517–527.

SOSEF, M. S. M. 1994. Glacial rainforest refuges and begonias. Wageningen Agric. Univ. Papers 94:113–121.

ULENBERG, S. A. 1985. The systematics of the fig wasp parasites of the genus *Apocrypta* Coquerel. Verh. K. ned. Akad. Wet., Tweede Reeks 83:1–176.

VAN NOORT, S. 1993a. Systematics of the sycoecine fig wasps (Agaonidae, Chalcidoidea, Hymenoptera), I (*Seres*). Proc. Kon. Ned. Akad. v. Wetensch. 96:233–251.

———. 1993b. Systematics of the sycoecine fig wasps (Agaonidae, Chalcidoidea, Hymenoptera), II (*Sycoecus*). Proc. Kon. Ned. Akad. v. Wetensch. 96:449–475.

———. 1994a. Systematics of the sycoecine fig wasps (Agaonidae, Chalcidoidea, Hymenoptera), III (*Crossogaster*). Proc. Kon. Ned. Akad. v. Wetensch. 97:83–122.

———. 1994b. Systematics of the sycoecine fig wasps (Agaonidae, Chalcidoidea, Hymenoptera), IV (*Philocaenus*, in part). Proc. Kon. Ned. Akad. v. Wetensch. 97:311–339.

———. 1994c. Systematics of the sycoecine fig wasps (Agaonidae, Chalcidoidea, Hymenoptera), V (*Philocaenus* concluded, generic key, checklist). Proc. Kon. Ned. Akad. v. Wetensch. 97:341–375.

VAN NOORT, S. AND S. G. COMPTON. 1999. Fig wasps (Agaonidae, Hymenoptera) and fig trees (Moraceae) of Mkomazi. Pp. 299–320 *in* Mkomazi: the ecology, biodiversity and conservation of a Tanzanian Savanna, M. J. Coe, N. C. McWilliam, G. N. Stone, and M. Packer, eds. Royal Geographical Society (with The Institute of British Geographers), London. 608 pp.

VAN NOORT, S. AND J. Y. RASPLUS. 1997. Revision of the otiteselline fig wasps (Hymenoptera, Chalcidoidea, Agaonidae), I: the *Otitesella digitata* species-group of the Afrotropical region, with a key to Afrotropical species of *Otitesella* Westwood. African Entomology 5:125–147.

WEST, S. A. AND E. A. HERRE. 1994. The ecology of the New World fig-parasitizing wasps *Idarnes* and implication for the evolution of the fig-pollinator mutualism. Proc. R. Soc. Lond. B 258:67–72.

WEST, S. A., E. A. HERRE, D. M. WINDSOR, AND P. R. S. GREEN. 1996. The ecology and evolution of the New World non-pollinating fig wasp communities. J. Biogeog. 23:447–458.

WHITE, F. 1983. The vegetation of Africa. A descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco, Paris.

WHITE, L. AND K. ABERNETHY. 1997. A Guide to the Vegetation of the Lopé Reserve. ECOFAC, Gabon. 224 pp.

WIEBES, J. T. 1979a. Coevolution of figs and their insect pollinators. Ann. Rev. Ecol. Syst. 10:1–12.

———. 1979b. The fig wasp genus *Dolichoris* Hill (Hymenoptera, Chalcidoidea, Agaonidae). Proc. Kon. Ned. Akad. v. Wetensch. 82:181–196.

———. 1979c. Fig wasps from Gabon: new species of *Agaon* (Agaonidae) and *Phagoblastus* (Torymidae) (Hymenoptera, Chalcidoidea). Proc. Kon. Ned. Akad. v. Wetensch. 82:391–400.

———. 1986. Agaonidae (Hymenoptera Chalcidoidea) and *Ficus* (Moraceae): fig wasps and their figs, I. Proc. Kon. Ned. Akad. v. Wetensch. 89:335–355.

———. 1988. Agaonidae (Hymenoptera Chalcidoidea) and *Ficus* (Moraceae): fig wasps and their figs, II (*Alfonsiella*). Proc. Kon. Ned. Akad. v. Wetensch. 91:429–436.

———. 1989. Agaonidae (Hymenoptera Chalcidoidea) and *Ficus* (Moraceae): fig wasps and their figs, V (*Agaon*). Proc. Kon. Ned. Akad. v. Wetensch. 92:395–407.

WIEBES, J. T. AND S. G. COMPTON. 1990. Agaonidae (Hymenoptera Chalcidoidea) and *Ficus* (Moraceae): fig wasps and their figs, VI (Africa concluded). Proc. Kon. Ned. Akad. v. Wetensch. 93:203–222.

On the Scorpions of Gabon and Neighboring Countries, with a Reassessment of the Synonyms Attributed to *Babycurus buettneri* Karsch and a Redescription of *Babycurus melanicus* Kovařík

Lorenzo Prendini

Division of Invertebrate Zoology, American Museum of Natural History
Central Park West at 79th St.
New York, NY 10024-5192
email: lorenzo@amnh.org

Results are presented from a study of recently collected scorpions from Gabon. The material is classified into three families and five species: *Babycurus buettneri* Karsch, 1886; *Babycurus melanicus* Kovařík, 2000; *Opisthacanthus africanus* Simon, 1876; *Opisthacanthus lecomtei* (Lucas, 1858); *Pandinus dictator* (Pocock, 1888). The taxonomic validity of synonyms attributed to *B. buettneri* is reassessed by examination of the type material. *Babycurus kirki* (Pocock, 1890) is synonymized with *B. buettneri*. *Babycurus johnstonii* Pocock, 1896 and *Babycurus neglectus* Kraepelin, 1896 are removed from synonymy with *B. buettneri* and *B. kirki*, respectively. The validity of *Babycurus centrurimorphus* Karsch, 1886 and *Babycurus pictus* Pocock, 1896, as distinct from each other and from *B. buettneri*, is upheld. *Babycurus melanicus*, newly recorded from Gabon and previously known only from the holotype, is redescribed on the basis of four new specimens. A key to the identification of the West African species of *Babycurus* is provided, and their distributions mapped. Additional records for *O. africanus*, *O. lecomtei*, *P. dictator*, *Pandinus imperator* (C. L. Koch, 1841) and *Pandinus gambiensis* Pocock, 1899 are provided from a study of previously undetermined museum material, and the distributions of these species are mapped. *Babycurus buettneri* and *O. africanus* are newly recorded from the Central African Republic, *P. dictator* is newly recorded from Gabon, and *O. lecomtei* is newly recorded from Bioko Island (Equatorial Guinea).

RÉSUMÉ

Ce travail présente les résultats d'une étude sur des scorpions récemment récoltés au Gabon. Les spécimens sont rapportés à 5 espèces représentant 3 familles distinctes: *Babycurus buettneri* Karsch, 1886; *Babycurus melanicus* Kovařík, 2000; *Opisthacanthus africanus* Simon, 1876; *Opisthacanthus lecomtei* (Lucas, 1858); *Pandinus dictator* (Pocock, 1888). La validité taxonomique des synonymes attribués à *B. buettneri* est réévaluée par examination des spécimens types. *Babycurus kirki* (Pocock, 1890) est synonyme de *B. buettneri*. *Babycurus johnstonii* Pocock, 1896 et *Babycurus neglectus* Kraepelin, 1896 sont respectivement exclus de la liste de synonymes de *B. buettneri* et *B. kirki*. La validité de *Babycurus centrurimorphus* Karsch, 1886 et *Babycurus pictus* Pocock, 1896, considérées comme étant dseux espèces distinctes entre elles et également différentes de *B. buettneri*, est retenue. *Babycurus melanicus*, trouvée pour la première fois au Gabon et seulement connue par l'holotype, est redécrite à partir de 4 nouveaux spécimens. Une

nouvelle clé de détermination des espèces de *Babycurus* pour l'Afrique de l'Ouest est établie ainsi que leur distribution. Des données additionnelles sur les espèces *O. africanus*, *O. lecomtei*, *P. dictator*, *Pandinus imperator* (C. L. Koch, 1841) et *Pandinus gambiensis* Pocock, 1899 ainsi que leur distribution sont présentées à la suite d'une étude de matériels de musées précédemment non-identifiés. *Babycurus buettneri* et *O. africanus* sont rapportées pour la première fois de la République du Centre-Afrique. *P. dictator* et *O. lecomtei* sont rapportées pour la première fois du Gabon et de l'île Bioko (Guinée Equatoriale).

No single work has treated the scorpion fauna of Gabon and neighboring West African countries. However, the species reported from this region have been variously covered in other general works (e.g., Belfield 1956) and most are fairly well known. According to the catalogues of Lamoral and Reynders (1975) and Fet et al. (2000), nine species in three families have been reported from this region. The recent description of a new species of *Babycurus* by Kovařík (2000) raised the total to ten (Table 1).

Although only five of these species had been previously reported from Gabon, additional species reported from neighboring Cameroon, Congo, and Equatorial Guinea were predicted to occur in Gabon. This prediction was confirmed during recent expeditions to Gabon in which 34 specimens were collected and classified into five species, representing three families—Buthidae: *Babycurus buettneri* Karsch, 1886 and *Babycurus melanicus* Kovařík, 2000; Liochelidae: *Opisthacanthus africanus* Simon, 1876 and *Opisthacanthus lecomtei* (Lucas, 1858); Scorpionidae: *Pandinus dictator* (Pocock, 1888). Seven scorpion species are now recorded from Gabon (Table 1).

All localities from Gabon, reported below, represent new records for *B. buettneri*, *B. melanicus*, *O. africanus*, *O. lecomtei* and *P. dictator*. *Babycurus melanicus* and *P. dictator* are newly reported from Gabon. Furthermore, the new records of *B. melanicus* from Gabon represent a considerable range extension for this species, until now known only from the holotype, originating in western DRC (Kovařík 2000). The discovery of four new specimens has prompted a redescription of *B. melanicus*.

Additional records of *O. africanus*, *O. lecomtei*, *P. dictator*, *Pandinus gambiensis* Pocock, 1899 and *Pandinus imperator* (C. L. Koch, 1841), from neighboring countries in West Africa, are provided from a study of previously undetermined museum material. These data provide new records for some of these species and assist in clarifying the distributional ranges suggested by Vachon (1967, 1970) and Lourenço and Cloudsley-Thompson (1996) for the three West African species of *Pandinus*.

The taxonomy and diagnostic characters of the nonbuthids, *O. africanus*, *O. lecomtei*, *P. dictator*, *P. gambiensis* and *P. imperator*, have been thoroughly addressed in the works of Belfield (1956), Vachon (1967, 1974), Lourenço (1982a, 1982b, 1987, 1991) and Lourenço and Cloudsley-Thompson (1996). However, confusion plagues the taxonomy of the buthids, especially *B. buettneri*, to which no fewer than five synonyms have been attributed by various authors (see Fet and Lowe 2000; Kovařík 2000). Much of this confusion can be attributed to the failure of previous authors to examine and compare the type specimens of *B. buettneri* and its putative synonyms, a situation that was unfortunately not resolved in the recent revision of *Babycurus* by Kovařík (2000). According to Kovařík (2000, pers. comm.), the holotype of *B. buettneri* was missing when he requested loan of the specimen from the Zoologisches Museum der Humboldt-Universität, Berlin (ZMB). Apparently, the holotype was officially loaned in 1982 to M. Vachon, who sent the specimen (without notification or approval from the ZMB), to the South African Museum, Cape

TABLE 1. Scorpion species recorded from Gabon (G) and neighboring West African countries: Cameroon (Ca); Equatorial Guinea, mainland (EG), Bioko Island (BI); Congo (Co); Angola, Cabinda (A); Democratic Republic of Congo (DRC). Species endemic to the region delimited by the outer borders of these countries are indicated with an asterisk. Unconfirmed records and taxonomically dubious species are omitted.

Family	Species	Ca	BI	EG	G	Co	A	DRC
Buthidae	*Babycurus buettneri* Karsch, 1886	×		×	×	×		
	Babycurus johnstonii Pocock, 1896*	×						
	Babycurus melanicus Kovařík, 2000*				×			×
	Hottentotta hottentotta (Fabricius, 1787)	×						
	Isometrus maculatus (De Geer, 1778)	×			×	×	×	×
	Lychasioides amieti Vachon, 1974*	×						
	Uroplectes occidentalis Simon, 1876	×			×	×	×	×
Liochelidae	*Opisthacanthus africanus* Simon, 1876*	×		×	×	×	×	×
	Opisthacanthus lecomtei (Lucas, 1858)*	×	×	×	×			
Scorpionidae	*Pandinus dictator* (Pocock, 1888)*	×	×	×	×	×		

Town (SAMC), where it remained until recently. According to F. Kovařík (pers. comm.), the SAMC did not react to an initial (1997) request that the specimen be returned to the ZMB but only returned the specimen three years later (2000). In the meantime, thinking that the holotype was lost, Kovařík (2000) selected and designated a neotype for *B. buettneri*. But by the time that the present contribution was in preparation, the holotype had been returned to ZMB and was loaned for examination. This investigation thus presents the first comparison of the holotype of *B. buettneri* with type and nontype material of its putative synonyms. As a result of this comparison, *Babycurus kirki* (Pocock, 1890) is synonymized with *B. buettneri*, whereas *Babycurus johnstonii* Pocock, 1896 and *Babycurus neglectus* Kraepelin, 1896 are removed from synonymy with *B. buettneri* and *B. kirki*, respectively. The validity of *Babycurus centrurimorphus* Karsch, 1886 and *Babycurus pictus* Pocock, 1896, as distinct from each other and from *B. buettneri*, is upheld. A key to the identification of the West African species of *Babycurus* is provided.

MATERIALS AND METHODS

Specimens from Gabon were collected mostly from pitfall traps in primary rainforest (B. Fisher and M. Burger, pers. comm.). However, a few were collected at night by searching with torchlight or during the day by turning stones, logs, tree bark, and inspecting other potential diurnal retreats.

Most of the specimens from Gabon are deposited in the collection of the California Academy of Sciences, San Francisco (CAS). Tissue samples of each species, stored in absolute ethanol, have been retained separately for DNA isolation and sequencing in the Ambrose Monell Collection for Molecular and Microbial Research (AMC) at the American Museum of Natural History, New York. Additional material examined is deposited in the following collections: American Museum of Natural History, New York (AMNH); The Natural History Museum, London (BMNH); Museum of Comparative Zoology, Harvard University, Cambridge (MCZ); Musée Royal de l'Afrique Centrale, Tervuren (MRAC); South African Museum, Cape Town (SAMC); Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt-am-Main (SMF); U. S. National Museum of Natural History, Smithsonian Institution, Washington, D. C. (USNM); Zoologisches Museum der Humboldt-Universität, Berlin (ZMB). Abbreviations for collections in which additional

type material, not examined, is deposited are as follows: Muséum National d'Histoire Naturelle, Paris (MNHN); Zoologisches Institut und Museum, Universität Hamburg (ZMH); František Kovařík Private Collection, Prague (FKPC).

Illustrations were produced using a stereomicroscope and camera lucida. Measurements were taken with digital calipers. Color designation follows the numbering system of Smithe (1974, 1975, 1981), trichobothrial notation follows Vachon (1974), and mensuration follows Stahnke (1970) and Lamoral (1979). Morphological terminology follows Couzijn (1976) for the segmentation of legs, Hjelle (1990) and Sissom (1990) for the segmentation of pedipalps, Prendini (2001) for metasomal carinae, and Stahnke (1970), Lamoral (1979), and Sissom (1990) for remaining features. Basal and apical rows of denticles on the fingers of pedipalp chelae are included in counts, following Sissom (1994), Lowe (2000) and Kovařík (2000). This method is considered less confusing than the alternative, variously employed by Kraepelin (1896), Vachon (1940a), Belfield (1956) and Probst (1973).

SYSTEMATIC SECTION

KEY TO THE WEST AFRICAN SPECIES OF *BABYCURUS*

1. Sternite VII with four granular carinae; metasomal segment V with ventromedian and ventrolateral carinae distinct, granular 2
   Sternite VII without granular carinae; metasomal segment V with ventromedian and ventrolateral carinae absent or obsolete 4
2. Fixed and movable fingers of pedipalp chela with six and seven rows of denticles, respectively . . . . *B. ugartei* Kovařík, 2000
   Fixed and movable fingers of pedipalp chela with eight and nine rows of denticles, respectively 3
3. Fingers of pedipalp chela each with a pair of external and internal accessory granules at the junction of the fused basal rows of denticles; subaculear tubercle not bifurcate . . . . . *B. johnstonii* Pocock, 1896
   Fingers of pedipalp chela each with a single external accessory granule at the junction of the fused basal rows of denticles; subaculear tubercle unequally bifurcate . . . . *B. melanicus* Kovařík, 2000
4. Metasomal segment V expanded distally in adult male, such that maximum width more than half length; fixed and movable fingers of pedipalp chela with six and seven rows of denticles, respectively . . . . *B. ansorgei* Hirst, 1911
   Metasomal segment V not expanded distally in adult male, maximum width less than half length; fixed and movable fingers of pedipalp chela with different numbers of rows of denticles 5
5. Fixed and movable fingers of pedipalp chela with seven and nine rows of denticles, respectively; movable finger of pedipalp chela with a pair of external and internal accessory granules at the junction of the fused basal rows of denticles; telson vesicle width more than half maximum width of metasomal segment V . . . . *B. buettneri* Karsch, 1886
   Fixed and movable fingers of pedipalp chela with nine and ten rows of denticles, respectively; movable finger of pedipalp chela with a single external accessory granule at the junction of the fused basal rows of denticles; telson vesicle width less than half maximum width of metasomal segment V . . . . *B. neglectus* Kraepelin, 1896

FAMILY BUTHIDAE

Babycurus buettneri Karsch

Babycurus büttneri Karsch, 1886:78, pl. III, fig. 1 (Type loc.: Sibango Farm, Gabon; holotype ♀: ZMB 4367); Kraepelin, 1895:89; Pocock, 1896:428–430; Kraepelin, 1899:62 (part); Pocock, 1899:835; Kraepelin, 1901:268; Kraepelin, 1913:181; Strand, 1916:140; Werner, 1916:86; Lampe, 1917:195; Pavlovsky, 1924:77; Pavlovsky, 1925:199; Werner, 1934:272; Werner, 1936:181; Vachon, 1940a:180, figs. 18, 22; Vachon, 1940b:251, 254, figs. 19, 21, 31, 35; Belfield, 1956:44; Probst, 1972:74.

Rhoptrurus kirki Pocock, 1890:137–138, pl. XIV, fig. 1 (Type loc.: West Africa; holotype ♂: BMNH 1865.60; synonymized by Kraepelin, 1899:62); Pocock, 1896:429.
Rhoptrurus büttneri: Pocock, 1890:138; Kraepelin, 1891:101, pl. II, fig. 23; Lönnberg, 1897:183; Kraepelin, 1898:3.
Babycurus kirki: Kraepelin, 1895:88; Pocock, 1899:835; Kraepelin, 1913:180; Werner, 1936:181–182, fig. 2; Vachon, 1940a:176–178; Belfield, 1956:44; Lourenço, 1986:200–203, figs. 1–4; Kovařík, 1998:104; Kovařík, 2000:248–250 (part), figs. 8, 20, 30, tab. 1–3 (part).
Babycurus buettneri: Werner, 1902:599; Moritz and Fischer, 1980:311; Fet and Lowe, 2000:77 (part); Kovařík, 2000:237–242 (part), figs. 4, 16 (?), tab. 1–3 (part).
Babycurus buttneri: Simon, 1903:123; Borelli, 1911:13; Roewer, 1943:216; Stahnke, 1972:122; Lamoral and Reynders, 1975:496–497 (part); Vachon, 1980:222, fig. 3; Lourenço, 1986:200–203; Dupré, 1990a:9; Warburg and Polis, 1990:229; Kovařík, 1998:104.
Tityus bahiensis: Kovařík, 1992:184 (part).

As noted above, the taxonomic validity of the synonyms attributed to *B. buettneri* [spelling accepted by Fet and Lowe (2000) according to Article 32 (i) (2) of the ICZN (1985)] remain contentious, despite a recent revision by Kovařík (2000). Kraepelin (1891) synonymized *B. centrurimorphus*, the type locality of which is allegedly in northwestern Madagascar, with *B. buettneri*, the type locality of which is in Gabon. Lamoral and Reynders (1975) observed that if *B. centrurimorphus* were truly synonymous with *B. buettneri*, then *B. buettneri* would be one of the most widely distributed scorpions of the Afrotropical region. Kraepelin (1896, 1899) regarded *B. centrurimorphus* as a valid species and did not repeat his previous synonymy with *B. buettneri*, a view adopted by some authors (e.g., Vachon 1940a; Probst 1973; Kovařík 1998, 2000), but not by others (e.g., Lamoral and Reynders 1975; Fet and Lowe 2000).

Similarly, the validity of *B. pictus*, described from Kenya, has remained uncertain. In the original description, Pocock (1896) suggested that this species might prove to be synonymous with *B. centrurimorphus*. Kraepelin (1896) subsequently synonymized it with *B. centrurimorphus*, a view accepted by some authors (e.g., Birula 1914, 1915a, 1915b; Probst 1973; Lamoral and Reynders, 1975; Kovařík 1998; Fet and Lowe 2000), but not by others (e.g., Fage and Simon 1936; Kovařík 2000).

The validity of *B. kirki* also remains ambiguous. Pocock (1896) first suggested that the holotype might be a mature individual of *B. buettneri*. Kraepelin (1896) reiterated this view, and subsequently (1899) synonymized this species with *B. buettneri*. Some authors (e.g., Lamoral and Reynders 1975; Fet and Lowe 2000) accepted this synonymy, but others (e.g., Vachon 1940a; Lourenço 1986; Kovařík 1998, 2000) did not.

Vachon's (1940a) synonymy of *B. neglectus* with *B. kirki* appears to have been forgotten by most authors (e.g., Belfield 1956; Lamoral and Reynders 1975; Lourenço 1986; Fet and Lowe 2000). However, Kovařík (1998, 2000) recently listed it as a junior synonym of *B. kirki*, following Vachon (1940a). Fet and Lowe (2000) considered this synonymy to be unjustified, and followed previous authors (except Vachon 1940a) in retaining *B. neglectus* as a valid species, distinct from *B. buettneri*.

In the most recent development, Kovařík (2000) synonymized *B. johnstonii* with *B. buettneri*, apparently by default, as he was unable to locate the holotype of *B. buettneri* (discussed above). According to Kovařík (2000:240–242):

B. kirki has been synonymized by Kraepelin (1899:62), and *B. centrurimorphus* by Kraepelin (1891:243) and Lamoral and Reynders (1975:497), with this species [*B. buettneri*]. In German museums (SMF, ZMB and ZMH) nearly all specimens labelled as *B. buettneri* agree with the

lectotype of *B. johnstonii*, and several other specimens belong to *B. kirki*. Most specimens of *B. kirki* in German museums were identified as *B. neglectus*. Since *B. centrurimorphus*, *B. johnstonii*, and *B. kirki* (= *B. neglectus*) are different species whose types I have examined, and since I have not found in all the museum materials any specimen labelled as *B. buettneri*, which could not be placed in one of the above three species anyway, I am convinced that one of these species really is a synonym of *B. buettneri*. Existence of the type of *B. buettneri* thus becomes very important. . . . To resolve the mutual position and validity of the above species . . . it is necessary to designate a neotype of *B. buettneri*. Since the holotype of *B. buettneri* was in ZMB, it can be assumed that Kraepelin had examined it. Therefore, I decided to designate as the neotype of *B. buettneri* an adult male which Kraepelin identified as *B. büttneri* and which is from the same locality as the holotype. Specimens that agree with the lectotype of *B. johnstonii* were commonly identified as *B. buettneri* by other German arachnologists, such as Werner and Roewer (unfortunately, there are no specimens identified by Karsch, who described *B. buettneri*), which is evidenced by examined specimens, as well as by published keys. Since I decided to designate a neotype only after seeing all the specimens identified as *B. buettneri*, my identification labels bear the name *B. johnstonii*.

The "rediscovery" of the holotype of *B. buettneri* invalidates Kovařík's (2000) premature neotype designation. Comparison of the holotype of *B. buettneri* with type and nontype material of its putative synonyms, as well as reassessment of the relevant diagnostic characters has resulted in the following conclusions, several of which differ from those of Kovařík (2000).

(1) The validity of both *B. centrurimorphus* and *B. pictus*, as distinct from *B. buettneri*, is upheld. Notwithstanding their disjunct geographical distributions (*B. centrurimorphus* and *B. pictus* occur in East Africa, whereas *B. buettneri* occurs in West Africa), *B. centrurimorphus* and *B. pictus* can be separated from *B. buettneri* according to the number of rows of denticles on the movable finger of the pedipalp chela (Table 2). Including the apical and fused basal rows, there are seven rows in *B. centrurimorphus* and *B. pictus*, compared with nine rows in *B. buettneri* (Kraepelin 1896, 1899; Vachon 1940a; Kovařík 2000).

(2) The validity of *B. pictus*, as distinct from *B. centrurimorphus*, is provisionally upheld, pending further investigation. The holotype of *B. pictus* displays the diagnostic character combination of *B. centrurimorphus* (Vachon 1940a; Probst 1973; Kovařík 2000): sternite VII and metasomal segments with ventrosubmedian and ventrolateral carinae absent or obsolete; pedipalp movable finger with seven rows of denticles (including the apical and basal rows); 18–19 pectinal teeth. However, the two species appear to be separable by means of differences in sexual dimorphism, notably the longer, narrower pedipalps of adult male *B. centrurimorphus*, as well as the smaller size of adult *B. pictus* (Kovařík 2000). Only the holotype female of *B. pictus* was examined during the present investigation. An independent comparison of additional material (including adult males of both species) should be conducted in order to resolve the issue conclusively.

(3) *Babycurus kirki* is again synonymized with *B. buettneri*. As noted by Pocock (1896) and Kraepelin (1896), the putative diagnostic differences between *B. kirki* and *B. buettneri* (see Vachon 1940a; Belfield 1956) can be ascribed to sexual dimorphism between the male and female holotypes. The ventromedian and ventrolateral carinae on metasomal segment V are obsolete to absent in the male, but weakly developed to obsolete in the female and the pedipalp chela manus of the male is broader than in the female

(Lourenço 1986; Kovařík 2000). Belfield's (1956) statement that carinae are present on sternite VII in *B. buettneri* is erroneous. Furthermore, this species is characterized by nine rows of denticles (including the apical row) on the movable finger of the pedipalp chela, not seven. Specimens with ten rows mentioned by Kovařík (2000) can be ascribed to *B. neglectus* not *B. buettneri*.

Lourenço (1986:200) examined the holotype of *B. kirki* and justified the validity of this species, as distinct from *B. buettneri*, on the basis of differences in habitat (forest vs. savanna): "La mise en synonymie de *B. kirki* avec *B. buttneri* a été admise sur des resemblances morphologiques; cependant, des différences morphologiques existent entre les deux espèces qui, de toute évidence, ne proviennent pas du même milieu: *B. buttneri* . . . est une espèce vraisemblablement forestiere, tandis que les *Babycurus* de Lamto (= *B. kirki*) ont été trouvés exclusivement dans les savanes." This ecological argument is unsupported by the new specimens from Gabon (collected in primary rainforest), which correspond closely with the holotypes of *B. buettneri* and *B. kirki*, as well as with Lourenço's (1986) revised diagnosis and meristics for *B. kirki* (Table 2).

(4) *Babycurus neglectus* is removed from synonymy with *B. kirki*. Although the type specimens of *B. neglectus* were not examined in the present study, three specimens from SMF, previously examined by Kovařík (2000), were found to be morphologically distinct from the holotypes of *B. buettneri* and *B. kirki* and the nontype specimens of *B. buettneri* from Gabon (Table 2). Vachon's (1940a) synonymy, recently adopted by Kovařík (1998, 2000), is thus rejected, based on the following combination of character states provided by Kraepelin (1891, 1896, 1899): metasomal segments with ventrosubmedian and ventrolateral carinae obsolete; pedipalp movable finger with ten rows of denticles (including the apical and fused basal rows); width of metasomal segments increasing distally; telson vesicle width less than half maximum width of metasomal segment V.

(5) *Babycurus johnstonii* is removed from synonymy with *B. buettneri*. Comparison of the lectotype and paralectotype of *B. johnstonii* with the holotypes of *B. buettneri* and *B. kirki* and the nontype specimens of *B. buettneri* from Gabon confirmed that these species are consistently separable on the basis of the following characters of Pocock (1896): sternite VII with four granular carinae in *B. johnstonii*, without carinae in *B. buettneri*; metasomal segment V with ventromedian and ventrolateral carinae distinct, granular in *B. johnstonii*, absent to obsolete in *B. buettneri*; fixed finger of pedipalp chela with eight rows of denticles in *B. johnstonii*, with seven rows in *B. buettneri*.

ECOLOGICAL NOTE. — In common with many buthids, *B. buettneri* appears to be opportunistic, using available shelter on the ground or in the forest canopy. Specimens from Gabon were collected in termite mounds, rotten logs and pitfall traps.

RANGE. — *Babycurus buettneri* may be one of the most widespread scorpions in West Africa (Fig. 1), with records confirmed from Senegal, Guinea, Côte d'Ivoire, Ghana, Togo, Nigeria, Cameroon, Equatorial Guinea, Congo and Gabon (Vachon 1940a; Belfield 1956; Lamoral and Reynders 1975; Lourenço 1986; Fet and Lowe 2000; Kovařík 2000). The species is newly recorded from the Central African Republic in the present study.

The widespread distribution of this species could be associated with its occurrence in a range of vegetation types, including primary lowland rainforest, relict gallery forest and savanna. Specimens for which data are available were collected at an elevation of 110–375 m. It should be noted that many literature records probably still reflect misidentifications of *B. neglectus* and perhaps *B. johnstonii*. A thorough re-examination of the specimens on which these records are based should be undertaken to accurately verify the distributional ranges of these species.

TABLE 2. Meristic data for *Babycurus buettneri* Karsch, 1886, *Babycurus centrurimorphus* Karsch, 1886, *Babycurus johnstonii* Pocock, 1896, *Babycurus melanicus* Kovařík, 2000, *Babycurus neglectus* Kraepelin, 1896 and *Babycurus pictus* Pocock, 1896. Measurements following Stahnke (1970) and Lamoral (1979). [1] Sum of metasomal segments I–V and telson. [2] Measured from base of condyle to tip of fixed finger. [3] Basal and apical rows included.

Specimen:		*B. buettneri*			
	Sex	♀	♀	♂	♂
	Collection	ZMB	CAS	BMNH	CAS
	Number	4367		1860.65	
	Type	holotype		holotype	
	Synonym			*B. kirki*	
Total length:	prosoma+mesosoma+metasoma	47.20	65.06	69.77	55.21
Carapace:	anterior width	2.88	4.02	4.73	3.54
	posterior width	4.68	6.99	7.22	5.66
	length	4.60	6.64	7.10	5.55
Mesosoma:	total length (tergites)	13.07	20.30	19.58	14.94
Sternite VII:	width	3.85	6.89	6.54	5.06
	length	3.34	4.22	4.84	3.06
Metasoma:	total length[1]	29.53	38.12	43.09	34.72
Metasoma I:	maximum width	2.72	3.68	4.08	2.90
	length	3.87	4.65	5.52	4.01
Metasoma II:	maximum width	2.68	3.48	4.13	2.93
	length	4.48	5.52	6.62	5.07
Metasoma III:	maximum width	2.65	3.43	4.22	2.96
	length	4.81	6.15	6.72	5.75
Metasoma IV:	maximum width	2.60	3.38	4.27	2.97
	length	5.10	6.75	7.58	6.24
Metasoma V:	maximum width	2.46	3.22	4.31	2.99
	length	6.22	8.29	9.13	7.66
Telson:	maximum width	1.61	2.46	3.12	2.15
	maximum height	1.60	2.21	2.65	1.99
	aculeus length	2.43	2.76	3.39	2.29
	total length	5.05	6.76	7.52	5.99
Pedipalp:	total length (including trochanter)	22.28	27.79	31.20	24.56
Chela:	maximum width	1.77	2.15	3.81	2.38
	maximum height	1.57	1.99	3.77	2.29
	length[2]	9.42	12.51	13.93	11.16
	length of ventroexternal carina	3.47	3.96	5.94	3.92
	length of movable finger	6.38	8.12	8.32	6.59
	rows of denticles fixed (left/right)	7/-	7/7	7/7	7/7
	rows of denticles movable[3] (left/right)	9/9	9/9	9/9	9/9
Patella:	maximum width	2.09	2.47	2.76	2.23
	length	5.97	7.38	7.62	5.98
Femur:	maximum width	1.53	1.84	1.99	1.69
	length	4.85	6.37	6.60	5.34
Pectines:	total length	4.24	4.57	6.36	4.83
	length along dentate margin	4.10	4.55	6.35	4.71
	tooth count (left/right)	19/19	18/17	19/19	18/18

TABLE 2. Meristic data (continued).

B. centrurimorphus		B. johnstonii	B. melanicus	B. neglectus	B. pictus
♀	♂	♀	♀	♀	♀
ZMB	ZMB	BMNH	CAS	SMF	BMNH
4307b	4307a	1890.3.18.1–2		RII/8873	1893.11.9.3
lectotype	paralectotype	lectotype			holotype
64.96	47.04	64.95	81.34	54.79	52.59
4.44	2.84	4.48	5.17	3.66	3.29
6.98	4.98	7.28	8.87	6.18	5.59
6.90	4.82	6.74	8.42	6.20	5.50
18.74	13.91	19.19	24.2	16.22	16.98
6.70	4.18	6.95	7.67	6.41	5.55
4.48	2.97	5.02	5.51	4.23	3.83
39.32	28.31	39.02	48.72	32.37	30.11
3.51	2.53	3.88	4.58	3.48	2.67
4.90	3.97	5.05	6.26	4.07	4.14
5.58	2.69	3.58	4.39	3.56	2.68
5.49	4.21	6.03	7.37	4.43	4.29
3.59	2.77	3.52	4.38	3.63	2.71
5.96	4.29	6.42	7.95	5.10	4.65
3.52	2.74	3.42	4.02	3.70	2.81
6.86	4.91	6.61	8.42	5.37	5.20
3.29	2.40	3.26	3.69	3.71	2.53
9.04	6.07	8.14	9.98	7.69	6.35
2.55	1.62	2.51	3.34	1.77	1.97
2.35	1.53	2.43	2.90	1.69	1.77
3.27	2.13	2.47	3.22	2.41	2.23
7.07	4.86	6.77	8.74	5.71	5.48
29.59	23.66	29.78	34.54	25.38	22.4
2.45	1.98	2.21	2.70	1.77	2.06
2.61	2.03	2.00	2.61	1.80	2.10
12.97	10.24	12.68	14.26	10.93	9.34
4.92	4.16	3.85	4.40	3.61	4.02
7.61	5.75	8.03	9.41	7.41	5.10
6/6	6/6	8/8	8/8	9/9	6/6
7/7	7/7	9/9	9/9	10/10	7/7
2.45	1.58	2.46	2.88	2.28	2.07
7.43	5.99	7.59	8.96	6.34	5.55
1.77	1.26	1.77	2.37	1.61	1.62
6.33	5.50	6.72	8.06	4.93	5.24
4.70	4.28	5.05	5.94	4.23	3.86
4.55	4.27	4.73	5.47	4.04	3.83
19/19	20/20	18/19	18/19	18/18	19/19

Babycurus centrurimorphus Karsch

Babycurus centrurimorphus Karsch, 1886:78–79, pl. III, fig. 2 (Type loc.: NW Madagascar [dubious]; lectotype ♀ [desig. Kovařík, 2000]: ZMB 4307b; ♂, 3♀ paralectotypes [desig. Kovařík, 2000]: ZMB 4307a); Kraepelin, 1895:89; Kraepelin, 1896:124 (part); Kraepelin, 1899:63 (part); Kraepelin, 1913:180, 182–183; Birula, 1914:119–120 (part); Birula, 1915a:16–17 (part); Birula, 1915b:51 (part); Fage, 1929:72; Fage and Simon, 1936:303; Werner, 1936:181; Vachon, 1940a:179, figs. 20, 24; Roewer, 1952:28; Geeraerts, 1953:1066; Probst, 1973:325 (part); Vachon, 1980:222; Moritz and Fischer, 1980:312; Warburg and Polis, 1990:234; Kovařík, 1998:104 (part); Kovařík, 2000:242–244 (part), figs. 17, 33–34, tab. 1–3.
Buthus (*Rhoptrurus*) *centrurimorphus*: Pocock, 1890:122.
Rhoptrurus büttneri: Kraepelin, 1891:101, 243.
Babycurus (*Rhoptrurus*) *centrurimorphus*: Kraepelin, 1901:268.
Babycurus buttneri: Lamoral and Reynders, 1975:496–497 (part).
Babycurus buettneri: Fet and Lowe, 2000:77 (part).

As discussed under *B. buettneri*, *B. centrurimorphus* is a distinct species. The diagnostic characters of this species were reviewed by Vachon (1940a), Probst (1973) and Kovařík (2000). A lectotype and paralectotypes were designated by Kovařík (2000).

RANGE. — The type locality of *B. centrurimorphus* is ambiguous. Although Karsch (1886) indicated that the type specimens originated in northwestern Madagascar, all remaining species of *Babycurus* have been described from specimens originating on the African mainland or the Arabian Peninsula (Lamoral and Reynders 1975; Sissom 1994; Fet and Lowe 2000; Lowe 2000; Kovařík 2000). No other specimens of *Babycurus* have been reported subsequently from Madagascar and Lourenço (1996) omitted *Babycurus* from his monograph on the Malagasy scorpion fauna. Probst (1973) speculated that the occurrence of *B. centrurimorphus* in Madagascar might be attributed to artificial importation. However, it is more parsimonious to conclude that the type specimens of *B. centrurimorphus* originated in East Africa and were erroneously labelled.

All confirmed records of *B. centrurimorphus* occur in East Africa, principally Kenya, Tanzania, Mozambique, and Rwanda (Probst 1973; Kovařík 2000). Kovařík (2000) suggested that the species may also occur in the DRC, following Roewer (1952), but this requires confirmation. Kovařík (2000) followed Probst (1973) in rejecting Kraepelin's (1913) record of *B. centrurimorphus* from Angola and suggested that Kraepelin may have misidentified *B. ansorgei*. Although Kovařík's (2000) suggestion is possibly correct, the same misidentification may be attributed to several specimens listed by him from "San Paolo de Loanda" (the old name for Luanda, which occurs in Angola not Tanzania). The latter specimens (ZMH 8180, 10182, 10186) may be conspecific with *B. ansorgei* or may represent an undescribed species (see also under *B. pictus*).

Babycurus johnstonii Pocock

Babycurus johnstonii Pocock, 1896:429–430 (Type loc.: Rio del Rey, near Old Calabar River, Cameroon-Nigeria border [Cameroon]; lectotype ♀, paralectotype ♀ [desig. Kovařík, 2000]: BMNH 1890.3.18.1–2); Pocock, 1899:835; Lamoral and Reynders, 1975:498; El-Hennawy, 1992:97, 111; Kovařík, 1998:104; Fet and Lowe, 2000:78.
Babycurus johnstoni: Kraepelin, 1899:63; Kraepelin, 1913:181; Borelli, 1925:323; Vachon, 1940a:180, figs. 19, 23; Belfield, 1956:44; Strinati, 1960:536.
Babycurus (*Rhoptrurus*) *johnstoni*: Kraepelin, 1901:268.
Babycurus buettneri: Kovařík, 2000: 237–242 (part), figs. 4, 16 (?), tab. 1–3 (part).

This species was, in part, redescribed as *B. buettneri* by Kovařík (2000), who also designated a lectotype and paralectotype. Diagnostic characters for *B. johnstonii* were provided in the keys of Vachon (1940a) and Belfield (1956) and the species can be separated from the remaining West African *Babycurus* by means of the key provided above. The subspecies, *Babycurus johnstonii ochraceus* Masi, 1912, described from Mogadiscio (Somalia), was tentatively synonymized with *Babycurus wituensis taramassoi* Borelli, 1919 by Kovařík (2000).

RANGE. — The type locality of *B. johnstonii* occurs on the Cameroon side of the border between Nigeria and Cameroon in an area of primary lowland rainforest (Fig. 1). Vachon (1940a) stated that *B. johnstonii* occurs from Cameroon to Togo, perhaps based on specimens in the MNHN. Strinati (1960) reported this species from former French Equatorial Africa (now Congo and Gabon). These reports require confirmation.

Babycurus melanicus Kovařík (Figs. 1–10)

Babycurus melanicus Kovařík, 2000:250, figs. 28, 37, tab. 1–3 (Type loc.: CDR (Zaïre) [Democratic Republic of Congo], west; holotype ♀ [not examined]: FKPC).
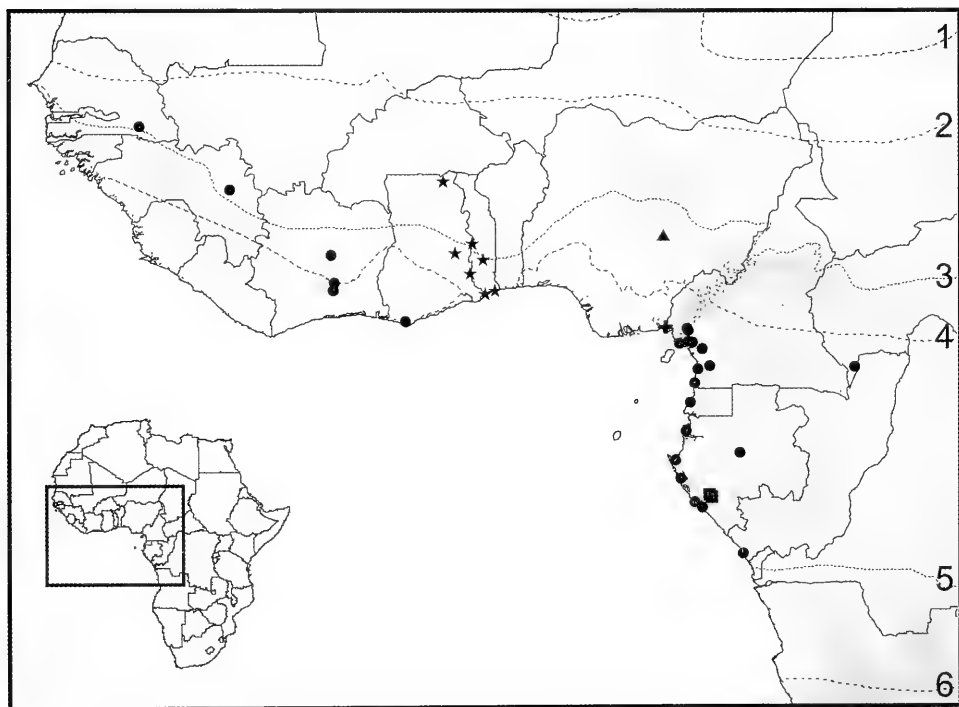
FIGURE 1. Map of West Africa illustrating the known distributional ranges of *Babycurus buettneri* Karsch, 1886 (circles), *Babycurus johnstonii* Pocock, 1896 (cross), *Babycurus melanicus* Kovařík, 2000 (squares), *Babycurus neglectus* Kraepelin, 1896 (stars) and *Babycurus ugartei* Kovařík, 2000 (triangle), based on data from Lamoral and Reynders (1975), Lourenço (1986), Kovařík (2000) and the present contribution. Numbered, dashed lines indicate the boundaries of major vegetation zones according to White (1983), such that: <1 = desert; 1-2 = semidesert; 2-3, >6 = arid to semiarid savanna; 3-4, 5-6 = moist savanna, with montane vegetation at high elevation; 4-5 = rainforest.
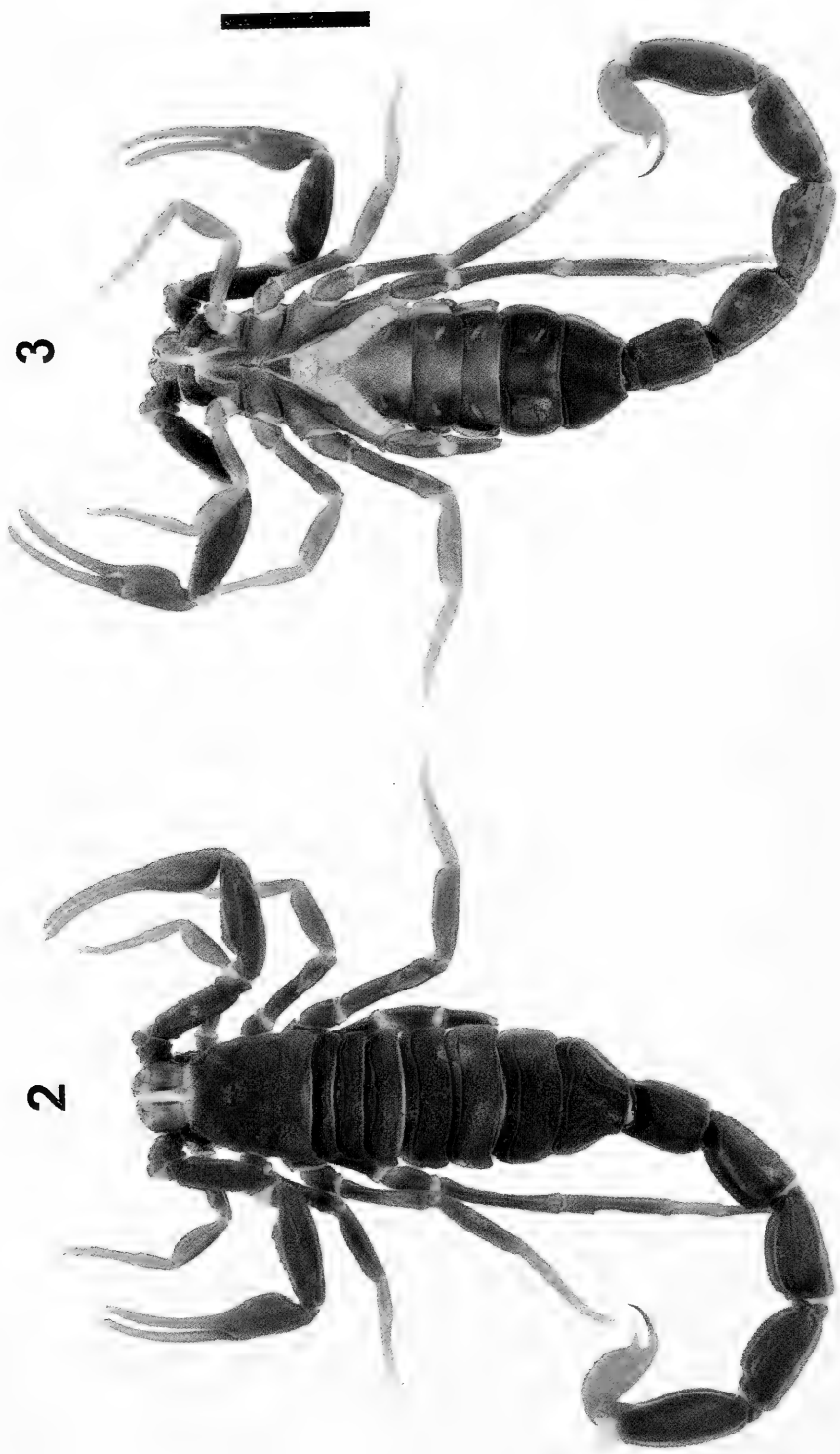
FIGURES 2–3. *Babycurus melanicus* Kovařík, 2000. (♀, CAS), habitus. 2. Dorsal aspect. 3. Ventral aspect. Scale bar = 10 mm.
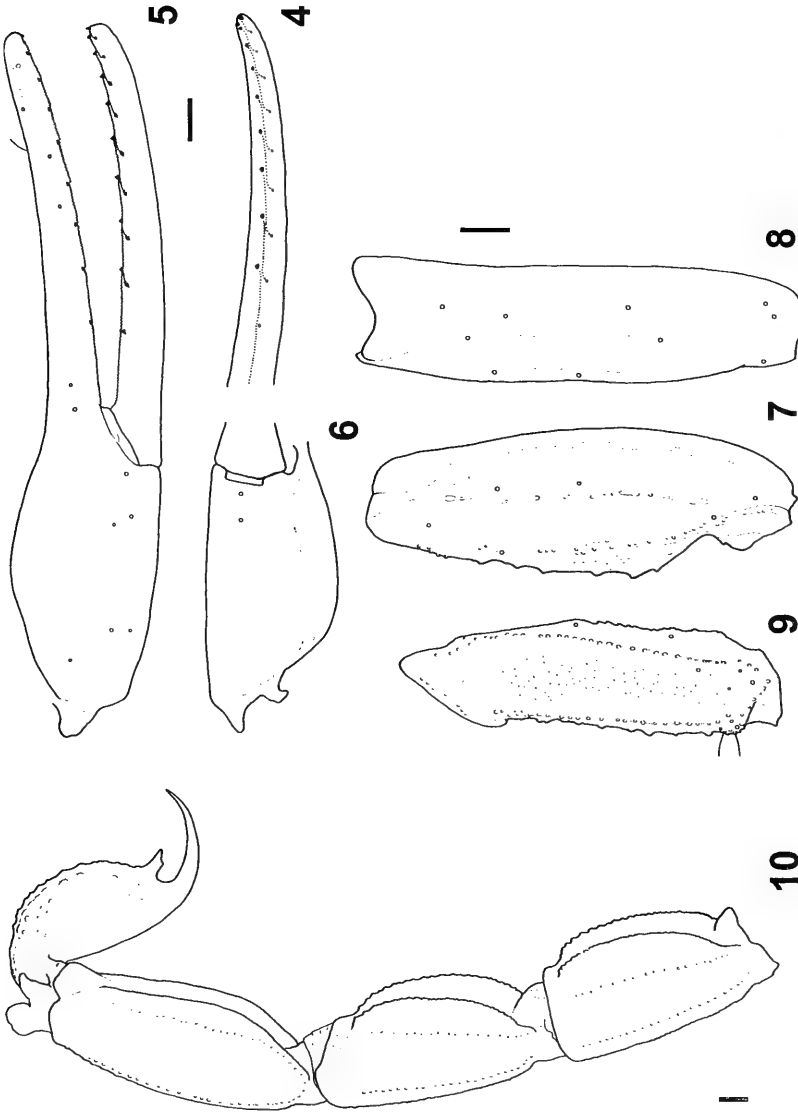
FIGURES 4–10. *Babycurus melanicus* Kovařík, 2000. (♀, CAS), diagnostic characters. 4. Cutting margin of dextral pedipalp chela movable finger, indicating dentition. 5–9. Distribution of trichobothria on the dextral pedipalp segments. 5. Dorsal aspect of chela. 6. Ventral aspect of chela. 7. Dorsal aspect of patella. 8. External aspect of patella. 9. Dorsal aspect of femur. 10. Lateral aspect of metasomal segments III–V and telson. Scale bar = 1 mm.

DIAGNOSIS. — *Babycurus melanicus* appears to be most closely related to *B. johnstonii*, with which it shares the following character states: sternite VII with four granular carinae; metasomal segment V with ventromedian and ventrolateral carinae distinct, granular; fixed finger of pedipalp chela with eight rows of denticles. Kovařík (2000) evidently drew the same conclusion when suggesting that *B. melanicus* was most closely related to *B. buettneri*, although that conclusion was predicated on the mistaken impression that *B. buettneri* and *B. johnstonii* were synonymous (discussed above).

Babycurus melanicus can be separated from *B. johnstonii* by means of the following character states: fingers of pedipalp chela each with a single external accessory granule at the junction of the fused basal rows of denticles; subaculear tubercle bifurcate. In *B. johnstonii*, the corresponding character states are as follows: fingers of pedipalp chela each with a pair of external and internal accessory granules at the junction of the fused basal rows of denticles; subaculear tubercle not bifurcate. The rufous coloration of the telson vesicle, contrasting with the black coloration of the carapace, mesosoma, metasoma, pedipalps and legs, is also diagnostic for *B. melanicus*. *Babycurus johnstonii* is characterized by uniform dark brown coloration of the metasomal segments and telson. Further color differences were provided by Kovařík (2000).

DESCRIPTION. — The following redescription is based on the largest female from Gabon (Figs. 2, 3). Differences between this specimen and the other three are provided in the section on variation.

Color: Carapace, tergites, metasomal segments I–V, pedipalps (excluding chelae) and dorsal surfaces of legs: Jet Black No. 89. Pedipalp chelae: Chestnut No. 32. Telson: Cinnamon-Rufous No. 40. Chelicerae, sternites, and ventral surfaces of legs: Clay Color No. 26. Pectines and genital operculum: Cream Color No. 54. Rufous telson contrasting markedly with black carapace, mesosoma, metasoma, pedipalps and legs.

Carapace: Carapace subrectangular, becoming wider posteriorly; anterior margin distinctly procurved, posterior margin straight. Entire carapace surface evenly, coarsely, and sparsely granular, except for ocular tubercle and posteromedian furrow, which are smooth. Three pairs of lateral ocelli. Median ocelli considerably larger than lateral ocelli, situated anteromedially. Ocular tubercle distinctly elevated above carapace surface, with pair of weakly granular superciliary carinae. All other carinae obsolete. Anteromedian furrow shallow, subovate; posteromedian furrow narrow, shallow anteriorly, becoming deeper posteriorly; posterolateral furrows shallow, wide, curved; posteromarginal furrow narrow, deep.

Chelicerae: Movable finger with distal external and distal internal teeth equal, opposable. Fixed finger with two ventral teeth. Ventral aspect of fingers and manus with long, dense macrosetae.

Sternum: Subtriangular. Median longitudinal furrow T-shaped, shallow anteriorly, deep and narrow posteriorly.

Pedipalps: Femur pentacarinate; carinae distinct, costate granular to granular, with spiniform granules on internomedian carina; dorsal and ventral intercarinal surfaces finely and evenly granular, lateral intercarinal surfaces smooth. Patella with seven distinct carinae; dorsointernal and dorsomedian carinae comprising several large spiniform granules, remaining carinae costate; intercarinal surfaces smooth, except for dorsointernal surface which is finely granular medially; basal tubercle weakly developed. Chela entirely smooth; dorsomedian, digital and ventroexternal carinae weakly developed but distinct, costate; other carinae obsolete. Chela long and slender, length along ventroexternal carina 39% greater than width and 41% greater than height; length of movable finger 53% greater

than length along ventroexternal carina. Dentate margins of fixed fingers each with eight oblique rows of denticles, rows 7–8 being fused into a single continuous row; dentate margins of movable fingers each with nine oblique rows of denticles, rows 8–9 being fused (Fig. 4); each row flanked proximally by internal and external accessory granules, except for the junctions of the fused basal rows of denticles, flanked only by an external accessory granule; two granules, proximal to the enlarged terminal denticle, flank the first row of each finger; supernumerary granules absent.

Trichobothria: Orthobothriotaxic, type A, β configuration (Figs. 5–9), with the following segment totals: femur, 11 (5 dorsal, 4 internal, 2 external), patella, 13 (5 dorsal, 1 internal, 7 external) and chela, 15 (8 manus, 7 fixed finger). Total number of trichobothria per pedipalp, 39.

Mesosoma: Pretergites entirely smooth, except on distal margins, which are finely granular. Post-tergites sparsely and coarsely granular, becoming more so on distal segments; II–VII each with a strongly developed, granular median carina; VII additionally with distinct pairs of granular dorsosubmedian and dorsolateral carinae. Sternites III–VI smooth; VII sparsely granular, with weakly developed pairs of granular ventrosubmedian and ventrolateral carinae.

Pectines: First proximal median lamella of each pecten with proximal corner acute. Pectinal teeth: 18/19.

Genital operculum: Completely divided longitudinally.

Legs: Tibia I–III without spurs. Basitarsi each with paired rows of long macrosetae and numerous microsetae on prolateral on retrolateral surfaces. Telotarsi each with a pair of ventrosubmedian rows of macrosetae and sparse setation on prolateral and retrolateral surfaces. Prolateral tarsal spurs with a basal bifurcation bearing a stout seta; retrolateral tarsal spurs simple. Telotarsal laterodistal lobes truncated; median dorsal lobes extending to ungues. Telotarsal ungues short, distinctly curved, and equal in length.

Metasoma and telson: Metasomal segments I–V progressively increasing in length, and decreasing in width, with segment V 19% narrower than segment I; width percentage of length 73% for I, 60% for II, 55% for III, 48% for IV, and 37% for V. Telson oval, with flattened dorsal surface and rounded ventral surface; vesicle moderately globose, slightly narrower than metasomal segment V, width 91% of metasomal segment V. Metasomal segments sparsely setose; ventral intercarinal surfaces smooth, but lateral and dorsal surfaces sparsely and finely granular; carinae costate granular to granular, becoming more weakly developed on distal segments; dorsal intercarinal surfaces each with a shallow median furrow. Segment I with ten carinae, II–IV with eight carinae, and V with five carinae. Median lateral carinae fully developed on segment I but absent in segments II–V. Segments I–IV with paired ventrosubmedian carinae whereas segment V with single ventromedian carina. Segment V with paired ventrolateral and dorsolateral carinae, dorsolateral carinae becoming obsolete distally; ventrolateral carinae converging distally. Telson sparsely and coarsely granular, with two parallel linear furrows extending from proximal edge to base of aculeus, and a well developed, spinoid subacular tubercle, unevenly bifurcated distally (Fig. 10). Aculeus long, 37% of vesicle length, and sharply curved.

Variation: The remaining specimens are similar in most respects, besides having a higher pectinal tooth count (19/20).

Measurements: As in Table 2.

ECOLOGICAL NOTE. — Available data suggest that this species is opportunistic, using available shelter on the ground. One specimen was collected from a rotten log, whereas the others were collected in pitfall traps.

RANGE. — Presently known only from the type locality (indefinitely located in western DRC) and the two, newly reported localities in Gabon (Fig. 1). This species appears to be endemic to primary lowland rainforest. The specimens from Gabon were collected at an elevation of 110–375 m.

Babycurus neglectus Kraepelin

Rhoptrurus dentatus (nec Karsch, 1879): Kraepelin, 1891:99, 241.
Babycurus neglectus Kraepelin, 1896:125 (Type loc.: Klein-Popo [Togo]; lectotype ♀, paralectotype ♂ [desig. Kovařík, 2000; not examined]: ZMH); Kraepelin, 1899:63–64; Werner, 1902:599; Kraepelin, 1913:180; Werner, 1916:86; Lampe, 1917:195; Werner, 1934:272, fig. 339; Roewer, 1943:216; Belfield, 1956:44; Lamoral and Reynders, 1975:498; Dupré, 1990a:9; Kovařík, 1992:182; Fet and Lowe, 2000:79.
Babycurus kirki: Vachon, 1940a:176–178 (part); Kovařík, 1998:104 (part); Kovařík, 2000:248–250 (part), figs. 7, 19, 29, tab. 1–3 (part).

This species was, in part, redescribed as *B. kirki* by Kovařík (2000), who also designated a lectotype and paralectotype. As discussed under *B. buettneri*, *B. neglectus* is a distinct species, which can be separated from the former, and from the remaining West African species of *Babycurus*, by means of the key provided above. Belfield's (1956) key provides additional diagnostic differences.

RANGE. — Kraepelin (1891, 1899) gives the distributional range of *B. neglectus* as "Gold Coast to Gaboon River" (Ghana to Gabon). However, the only confirmed locality records available for this species occur in the Dahomey gap, a region of savanna in Ghana, Togo, and Benin (Fig. 1). It is not known whether the distributional range of *B. neglectus* extends into the lowland rainforests of the Congo basin, or whether the records from Gabon are merely misidentifications of *B. buettneri*.

Babycurus pictus Pocock

Babycurus pictus Pocock, 1896:426–430, pl. XVIII, fig. 1 (Type loc.: Athi Plains, Kenya; holotype ♀: BMNH 1893.11.9.3); Pocock, 1898:430; Fage and Simon, 1936:303; Kovařík, 2000:242–244, figs. 17, 33–34, tab. 1–3.
Babycurus centrurimorphus: Kraepelin, 1896:124 (part); Kraepelin, 1899:63 (part); Birula, 1914:119–120 (part); Birula, 1915a:16–17 (part); Probst, 1973:325 (part); Kovařík, 1998:104 (part).
Babycurus buttneri: Lamoral and Reynders, 1975:496–497 (part).
Babycurus buettneri: Fet and Lowe, 2000:77 (part).

As discussed under *B. buettneri*, the validity of *B. pictus*, as distinct from *B. centrurimorphus*, is provisionally upheld on the basis of differential sexual dimorphism in the adult male presented by Kovařík (2000), but the matter requires further investigation.

RANGE. — All except one confirmed record occur in Kenya and Tanzania (Probst 1973; Kovařík 2000). Kovařík (2000) reported a single male specimen from Angola, differing from typical specimens by its larger size and the presence of costate carinae on the pedipalp chela. This specimen is doubtfully referable to *B. pictus* and may represent an undescribed species [perhaps conspecific with the abovementioned Angolan specimens identified as *B. centrurimorphus* by Kovařík (2000)], rather than a subspecies of the former, as suggested by Kovařík (2000).

FAMILY LIOCHELIDAE

Opisthacanthus africanus Simon

?*Scorpio 7-dentatus* Beauvois, 1805:191, pl. V, fig. 5 (Type loc.: unknown; holotype: lost; synonymized by Kraepelin, 1894:123).
Opisthacanthus africanus Simon, 1876:221–222 (Type loc.: Landana, Congo [now Cabinda, Angola]; holotype ♂ [not examined]: MNHN RS 289); Kraepelin, 1894:123–125; Kraepelin, 1898:4; Kraepelin, 1899:149; Pocock, 1899:837; Kraepelin, 1901:272; Werner, 1902:603; Simon, 1904:444; Borelli, 1911:13; Kraepelin, 1911:76; Hewitt, 1912:307; Borelli, 1913:220; Giltay, 1929:17; Kraepelin, 1929:89; Bacelar, 1950:5; Belfield, 1956:45; Newlands, 1973:92; Lamoral and Reynders, 1975:544–545; Lourenço, 1979:30; Lourenço, 1982b:147–153, figs. 1–14; Lourenço, 1987:904–905, pl. IV, figs. 9–11; Lourenço, 1991:31; Kovařík, 1998:134; Fet, 2000a:403–404.
Opisthacanthus septemdentatus: Karsch, 1879:372–373; Lourenço, 1979:29.
Opisthocentrus africanus: Pocock, 1893:317–318.

Opisthacanthus africanus was redescribed by Lourenço (1982b), who rediscovered the holotype in the collection of the MNHN. Lourenço (1987) provided additional diagnostic differences and mapped the known distributional range. The most closely related species of *Opisthacanthus* (subgenus *Nepabellus*) occur in southern and eastern Africa (Lourenço 1987, 1991).

ECOLOGICAL NOTE. — The morphology of the telotarsi (notably the strongly curved ungues and, to a lesser extent, the dactyl) is indicative of an arboreal habit. This species is known to inhabit holes in tree trunks and the spaces behind peeling bark, but has also been collected at ground level (Newlands 1973). The two recently collected specimens from Gabon were obtained in a rotten log and a pitfall trap, respectively.

RANGE. — Specimens of *O. africanus* are well represented in collections, with locality records confirmed from Angola, Cameroon, Congo, the DRC, Equatorial Guinea, and Gabon (Fig. 11). The species is newly recorded from the Central African Republic in the present study (CAS).

Records from Mozambique (Bacelar 1950) and South Africa (Kraepelin 1894, 1899; Hewitt 1912) are referable to *Opisthacanthus asper* (Peters, 1961) or *Opisthacanthus validus* Thorell, 1876. Reports from Guinea (Pocock 1893, 1899) and Sierra Leone (Kraepelin 1899, 1929), if confirmed, would support Belfield's (1956) suggestion that *O. africanus* occurs all along the West African coast. However, as no other records have been reported west of Cameroon, this is extremely doubtful. *Opisthacanthus africanus* appears to be endemic to primary lowland rainforest in the Congo basin. Specimens for which data are available were collected at an elevation of 110 m.

Opisthacanthus lecomtei (Lucas)

Scorpio (*Ischnurus*) *lecomtei* Lucas, 1858:428 (Type loc.: indefinite locality in West Africa [Gabon?]; holotype: MNHN [lost]; neotype ♂ [desig. Lourenço, 1982a; not examined]: MNHN RS 4627, Yaoundé, Ototomo forest reserve, Cameroon).
Opisthacanthus duodecimdentatus Karsch, 1886:79 (Type loc.: Sibango Farm, Gabon; holotype ♂: ZMB 4369 [not examined]; synonymized by Kraepelin, 1894:122); Lourenço, 1979:30; Moritz and Fischer, 1980:314.
Opisthocentrus lecomtei: Pocock, 1893:318; Pavlovsky, 1925:200.
Opisthacanthus lecomtei: Kraepelin, 1894:122–123, pl. II, fig. 50; Kraepelin, 1899:149; Pocock, 1899:836; Kraepelin, 1901:272; Simon, 1903:123; Kraepelin, 1911:73; Strand, 1916:140;
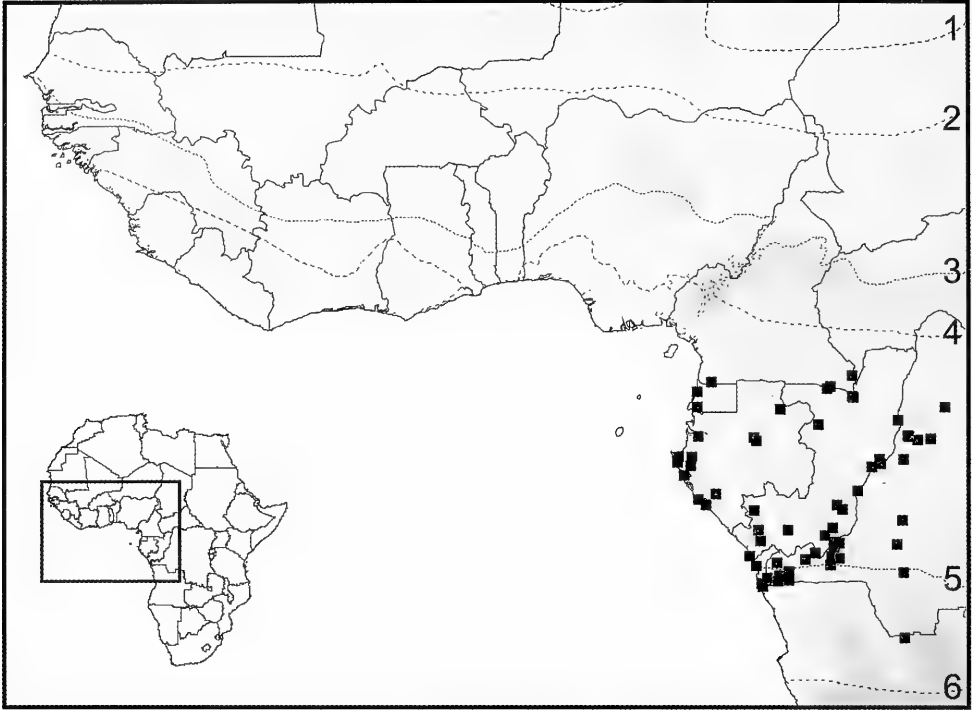
FIGURE 11. Map of West Africa illustrating the known distributional range of *Opisthacanthus africanus* Simon, 1876 (squares), based on data from Lamoral and Reynders (1975), Lourenço (1987) and the present contribution. Numbered, dashed lines indicate the boundaries of major vegetation zones according to White (1983), such that: <1 = desert; 1-2 = semidesert; 2-3, >6 = arid to semiarid savanna; 3-4, 5-6 = moist savanna, with montane vegetation at high elevation; 4-5 = rainforest.

Werner, 1916:91; Lampe, 1917:200; Werner, 1934:279; Roewer, 1943:234; Belfield, 1956:45; Newlands, 1973:92; Lamoral and Reynders, 1975:547; Lourenço, 1979:29; Lourenço, 1982a:1163–1168, figs. 1–13; Lourenço, 1987:900–901, pl. III, figs. 5–9; Lourenço, 1991:31; Nenilin and Fet, 1992:21; Lourenço, 1995:79; Kovařík, 1998:134; Fet, 2000a:401–402.

Opisthacanthus lecomtei was redescribed by Lourenço (1982a), who designated a neotype from the Ototomo forest reserve, Cameroon. Lourenço (1987) provided additional diagnostic differences and mapped the known distributional range.

The most closely related species of *Opisthacanthus* (subgenus *Opisthacanthus*) occur in northern South America (Lourenço 1987, 1991, 1995), which has elicited some debate on the zoogeography of the genus. The recognition of five Neotropical species of *Opisthacanthus* (Lourenço 1987, 1991, 1995) suggests that West African elements of the genus had reached the neotropics prior to the African disjunction in the late Cretaceaous, where they subsequently evolved in isolation (Lamoral 1980). This invalidates both Newlands' (1973, 1978) trans-Atlantic rafting hypothesis and Francke's (1974) generic relimitation.

ECOLOGICAL NOTE. — The morphology of the telotarsi (notably the strongly curved ungues and enlarged dactyl) is indicative of an arboreal habit. In Gabon, specimens were observed at night sitting on tree trunks several metres above the ground (M. Burger, pers. comm.). This species presumably inhabits holes in tree trunks and the spaces behind peel-
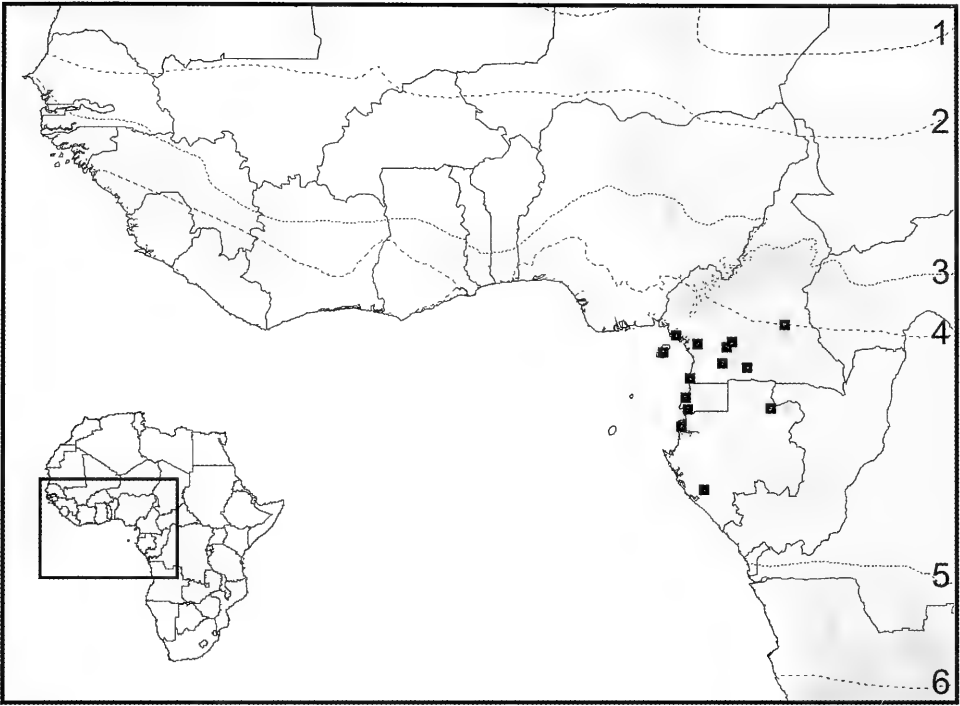
FIGURE 12. Map of West Africa illustrating the known distributional range of *Opisthacanthus lecomtei* (Lucas, 1858) (squares), based on data from Lamoral and Reynders (1975), Lourenço (1987) and the present contribution. Contour interval = 500 m. Numbered, dashed lines indicate the boundaries of major vegetation zones according to White (1983), such that: <1 = desert; 1-2 = semidesert; 2-3, >6 = arid to semiarid savanna; 3-4, 5-6 = moist savanna, with montane vegetation at high elevation; 4-5 = rainforest.

ing bark (Newlands 1973, 1978). The only other specimen for which ecological data are available was sifted from leaf litter.

RANGE. — Specimens of *O. lecomtei* are fairly well represented in collections. Almost all locality records occur in southwestern Cameroon and Gabon (Fig. 12), where the species is evidently endemic to montane rainforest. The two specimens for which data are available were collected at an elevation of 580–630 m. MRAC 134.274 represents the first record of this species from Bioko Island (Equatorial Guinea).

FAMILY SCORPIONIDAE

Pandinus dictator (Pocock)

Scorpio dictator Pocock, 1888:251–253 [Type loc.: Fernando Po (Bioko Island, Equatorial Guinea); holotype ♀: BMNH 1854.34]; Kraepelin, 1894:70–73, pl. I, figs. 16–17.
Pandinus dictator: Kraepelin, 1899:123, fig. 35; Kraepelin, 1901:270; Pocock, 1899:836; Werner, 1916:90; Lampe, 1917:199; Birula, 1927:87–88; Kraepelin, 1929:89; Werner, 1936:185; Kästner, 1941:234; Roewer, 1943:229; Belfield, 1956:45; Bücherl, 1964:59; Lourenço and Cloudsley-Thompson, 1996:133–136, figs. 2, 16–17; Kovařík, 1998:140.
Pandinus (*Pandinopsis*) *dictator*: Vachon, 1974:953, figs. 100, 113–115; Lamoral and Reynders, 1975:565; Kovařík, 1992:186; Kovařík, 1997:183; Fet, 2000b:470.

Although *P. dictator* has not been redescribed since its original description, the diagnostic characters of this species have been thoroughly elaborated in three papers. Belfield's (1956) key reviewed traditional diagnostic differences in the pectinal tooth count and the surface ornamentation of the carapace, terga and pedipalp chela manus between *P. dictator* and the closely related *P. imperator* and *P. gambiensis* (as *P. imperator gambiensis*). Vachon (1974) presented a new key, wherein diagnostic differences in the numbers and relative positions of pedipalp trichobothria were demonstrated among the three species, transferred *P. dictator* to a new subgenus, *Pandinopsis*, and retained the other two species, which are evidently more closely related, in the subgenus *Pandinus*. Lourenço and Cloudsley-Thompson (1996) summarized the differences presented by Vachon (1974) and discussed the known distributional range of the three species. All three species are protected by CITES due to overexploitation for the international trade in exotic pets (IUCN 1994).

ECOLOGICAL NOTE. — The thickened metasoma, short, robust legs with stout, spiniform macrosetae distributed laterally and distally on the basitarsi, and curved telotarsal ungues of *P. dictator* are indicative of a fossorial habit. As with the closely related *P. imperator* and *P. gambiensis*, *P. dictator* constructs burrows in termite mounds and under stones or logs (Newlands 1987). It is not known whether these burrows are occupied by more than one individual, as is the case with *P. imperator* (Toye 1970; Polis and Lourenço 1986; Mahsberg 1990).

RANGE. — Specimens of *P. dictator* are reasonably common in collections and, as is the case with *O. lecomtei*, this species appears to have a fairly restricted distributional range. All confirmed locality records occur in Cameroon, Congo, Equatorial Guinea (including Bioko Island, the type locality), and Gabon (Fig. 13), from which *P. dictator* is newly recorded in the present study (MRAC 132.725, CAS). Lourenço and Cloudsley-Thompson (1996) suggested that this species might also occur in southeastern Nigeria, but this seems unlikely as the Massif de l'Adamaoua, between Cameroon and Nigeria, appears to be an agent of vicariance, separating the distributional ranges of *P. dictator* and *P. imperator* (see below). *P. dictator* is endemic to lowland and montane rainforest, having been recorded at an elevation of 110–640 m.

Pandinus gambiensis Pocock

Pandinus imperator gambiensis Pocock, 1899:836 (Type loc.: Gambia; holotype ♂: BMNH 1895.7); Birula, 1910:143; Belfield, 1956:45.
Pandinus gambiensis: Vachon, 1967:1534–1537, figs. 1, 3–5, 9–11; Lourenço and Cloudsley-Thompson, 1996:133–136, figs. 3, 18–19; Kovařík, 1998:140.
Pandinus (Pandinus) gambiensis: Vachon, 1974:953; Lamoral and Reynders, 1975:566; Prost, 1982:7; Fet 2000b:466.

Vachon (1967) first realized the distinction between *Pandinus gambiensis* and its sister species, *P. imperator*, which can be separated by differences in granulation, the number of telotarsal spiniform setae, and the relative positions of pedipalp trichobothria (Belfield 1956; Vachon 1967, 1974; Lourenço and Cloudsley-Thompson 1996).

ECOLOGICAL NOTE. — Ecological data are absent for *P. gambiensis*, but are expected to be similar to *P. imperator*. The thickened metasoma, short, robust legs with stout, spiniform macrosetae distributed laterally and distally on the basitarsi, and curved telotarsal ungues are indicative of a fossorial habit. The species presumably constructs bur-
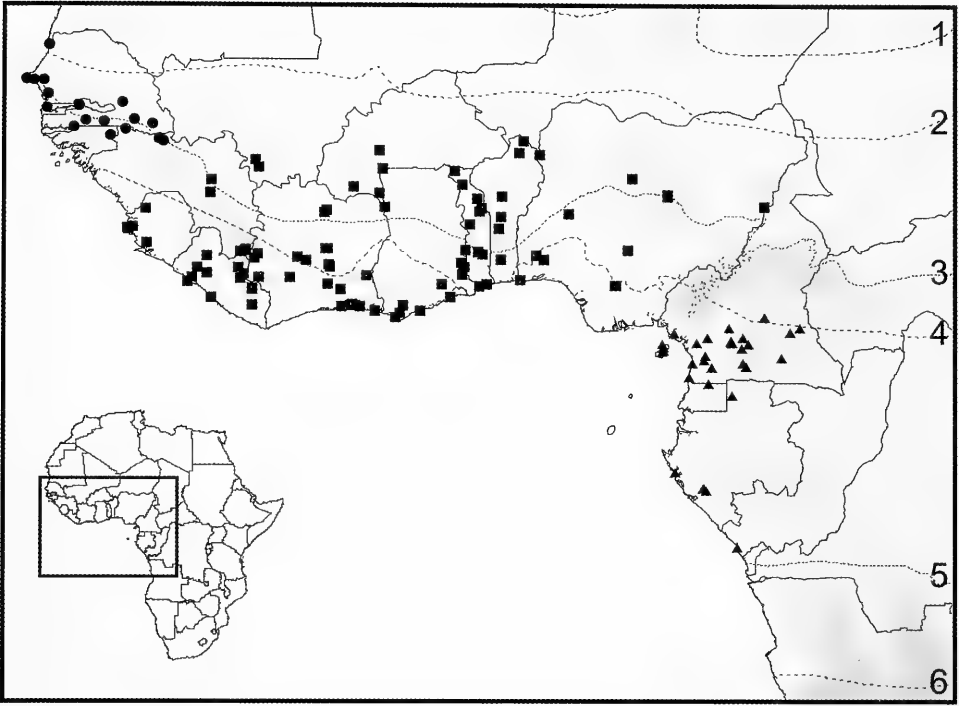
FIGURE 13. Map of West Africa illustrating the known distributional ranges of *Pandinus dictator* (Pocock, 1888) (triangles), *Pandinus gambiensis* Pocock, 1899 (circles), and *Pandinus imperator* (C. L. Koch, 1841) (squares), based on data from Vachon (1970), Lamoral and Reynders (1975) and the present contribution. Contour interval = 500 m. Numbered, dashed lines indicate the boundaries of major vegetation zones according to White (1983), such that: <1 = desert; 1-2 = semidesert; 2-3, >6 = arid to semiarid savanna; 3-4, 5-6 = moist savanna, with montane vegetation at high elevation; 4-5 = rainforest.

rows under stones or logs, which may be occupied by more than one individual, as in the latter species (Toye 1970; Polis and Lourenço 1986; Mahsberg 1990).

RANGE. — *Pandinus gambiensis* is endemic to savanna in Gambia, Senegal, Guinea-Bissau, and northern Guinea (Fig. 13). Vachon (1967, 1970) referred specimens from Boromo Somo (Burkina Faso) to *P. gambiensis*, but this is questionable. Prost (1982) and Lourenço and Cloudsley-Thompson (1996) referred records from Burkina Faso to *P. imperator*.

The distributional range of *P. gambiensis* is allopatric with that of its sister species, *P. imperator* (Vachon 1970; Lourenço and Cloudsley-Thompson 1996). Reports from Côte d'Ivoire (Fet 2000b) are referable to the latter. The conservation status of *P. gambiensis* is presently unknown, but the restricted range of this species is cause for concern.

Pandinus imperator (C. L. Koch)

Buthus afer (nec *Scorpio afer* Linnaeus, 1758): C. L. Koch, 1836:17, pl. LXXIX, fig. 175 (part); ?Guérin Méneville, 1843:9.
Buthus imperator C. L. Koch, 1841:1–2, pl. CCLXXXIX, fig. 695 (Type loc.: unknown; types: lost); C. L. Koch, 1850:87.
Heterometrus roeseli Simon, 1872:53–54, pl. VI, fig. 4 (Type loc: Guinea; type(s): MNHN [not examined]; synonymized by Thorell, 1893:377).

255

Heterometrus imperator: Simon, 1872:55–56.
Pandinus africanus Thorell, 1876:128, 202–203 (Type loc.: unknown; types not designated; synonymized by Fet 2000b:466).
Pandinus imperator: Thorell, 1876:130; Kraepelin, 1899:122–123; Pocock, 1899:836; Kraepelin, 1901:270; Werner, 1902:602; Birula, 1913:419; Borelli, 1913:220; Lampe, 1917:199; Pavlovsky, 1924:78; Birula, 1927:87–88; Werner, 1934:278, fig. 349; Werner, 1936:185; Vachon, 1940a:180; Kästner, 1941:234; Roewer, 1943:229; Frade, 1947:269; Bacelar, 1950:4; Roewer, 1952:32; Takashima, 1952:33; Vachon, 1952:13–15, figs. 7–12; Belfield, 1956:45; Bücherl, 1964:59; Vachon, 1967:1534–1537, figs. 1–2, 6–8; Garnier, 1973:1813–1816; Vachon, 1974, fig. 96; Prost, 1982:7; Lourenço, 1986:200; Kovařík, 1992:186; Lourenço and Cloudsley-Thompson, 1996:133–136, figs. 1, 10–14; Kovařík, 1998:140.
Scorpio simoni Becker, 1880:137–140, pl. II, fig. 1 [Type loc.: unknown; types possibly in Musée Royal d'Histoire Naturelle de Belgique, Bruxelles, Belgium (Fet 2000b:466); synonymized by Thorell, 1893:377].
Scorpio roeseli: Becker, 1880:137–140, pl. II, fig. 2; Pocock, 1888:253–254.
Scorpio imperator: Becker, 1880:137–140, pl. II, fig. 3; Pocock, 1888:254.
Pandinus africanus: Thorell, 1893:377–379; Karsch, 1884:68; Pavesi, 1895:39; Pavesi, 1897:157.
Scorpio africanus: Kraepelin, 1894:62–65 (part), pl. I, figs. 23, 25; Kraepelin, 1898:4–5.
Scorpio africanus typicus: Kraepelin, 1894:69.
Pandinus imperator typicus: Kraepelin, 1899:123.
Pandinus (Pandinus) imperator: Vachon, 1974:953; Lamoral and Reynders, 1975:566–567; Dupré, 1990a:9; El-Hennawy, 1992:100, 138; Kovařík, 1997:184; Fet, 2000b:466–467.

Pandinus imperator is the best known of the three West African species of the genus. Diagnostic differences between *P. imperator* and the related species, *P. gambiensis* and *P. dictator*, are summarized by Belfield (1956), Vachon (1967, 1974) and Lourenço and Cloudsley-Thompson (1996). The taxonomic validity of the subspecies *Pandinus imperator subtypicus* (Kraepelin, 1894), described from Habab, Abyssinia (now Eritrea) is uncertain. This may represent a distinct species, or a synonym of one of the 20 species of *Pandinus* described from northeastern Africa.

The ecology, behavior, and physiology of *P. imperator* have been extensively studied (e.g., Toye 1970; Garnier and Stockmann 1973; Casper 1985; Mahsberg 1990). This species is readily obtained from pet stores in Europe, the U. S. A., and Japan and there is an extensive literature on captive husbandry and breeding (e.g., Larrouy et al. 1973; Garnier 1974; Krapf 1988; Copeland 1990; Dupré 1990b; Montambaux 1996; Schiejok 1997; Mahsberg et al. 1999). The remaining wild populations are threatened not only by the exotic pet trade, but also by continuing destruction of their habitat through deforestation. However, the decline in this species may be partially alleviated by its recent CITES status (IUCN 1994; Lourenço and Cloudsley-Thompson 1996) and the increasing preference for captive-bred specimens in the pet trade (R. D. Gaban, pers. comm.).

ECOLOGICAL NOTE. — *Pandinus imperator* inhabits primary rainforest, relict gallery forest, and savanna (Toye 1970; Vachon 1970; Lourenço 1986; Mahsberg 1990; Lourenço and Cloudsley-Thompson 1999). Vachon (1952) reported specimens collected from primary rainforest in Guinea at an elevation of 500–1250 m. Two ecotypes, corresponding to forest and savanna populations, have been reported from the Côte d'Ivoire (Garnier and Stockmann 1972; Garnier 1973; Lourenço and Cloudsley-Thompson 1996, 1999).

As with other species of the genus, *P. imperator* constructs burrows using the short, robust legs with stout, spiniform macrosetae distributed laterally and distally on the basitarsi, and the thickened metasoma (Newlands 1987). Burrows are preferentially constructed in termite mounds and under stones or logs, and may contain up to 20 individuals, with the largest individual nearest the entrance (Toye 1970; Polis and Lourenço 1986; Mahsberg

1990). Mixed age groups of related and unrelated individuals cohabit with minimal aggression or cannibalism in laboratory terraria, and group living has been demonstrated to contribute significantly to postembryonic growth rate and survival probability, especially among kin (Mahsberg 1990; Kriesch 1994).

Pandinus imperator is known for its unusual activity rhythms. Diurnal activity has frequently been observed in this species, which may appear on the surface in large numbers, especially after rains (Toye 1970; Newlands 1987).

RANGE. — As indicated by Vachon (1967, 1970) and Lourenço and Cloudsley-Thompson (1996), the distributional range of *P. imperator* extends from Guinea and Sierra Leone, through Liberia, Côte d'Ivoire, Ghana, Togo and Benin, into eastern Nigeria (Fig. 13). Records from Mali (Vachon 1970) and Burkina Faso (Vachon 1970; Prost 1982) are unconfirmed.

Reports of *P. imperator* from Guinea-Bissau (Frade 1947; Bacelar 1950) and Senegal (Werner 1936) are referable to *P. gambiensis*, whereas reports from Congo, Equatorial Guinea and Gabon (Pocock 1899; Lamoral and Reynders 1975; Fet 2000b) are referable to *P. dictator*. Reports from East Africa (Kraepelin 1894, 1898; Pavesi 1895, 1897; Roewer 1952; Fet 2000b) are referable to other species of *Pandinus*.

Pandinus imperator is allopatric with *P. gambiensis* and *P. dictator* (Vachon 1967; Lourenço and Cloudsley-Thompson 1996). The Massif de l'Adamaoua, between Cameroon and Nigeria, appears to be the agent of vicariance, separating the distributional ranges of *P. imperator* and *P. dictator*, which evidently display similar habitat predilections. The agent of vicariance separating the distributional ranges of *P. gambiensis* and *P. imperator* is unclear, but may be associated with climatic variables, e.g., northwardly decreasing rainfall.

DISCUSSION

The region encompassed by Cameroon, Equatorial Guinea, and Gabon contains the highest species richness and endemism of scorpions in tropical West Africa. Nine species are recorded from Cameroon alone (ca. 475,000 km^2), whereas only four species are recorded from the region encompassed by Côte d'Ivoire and Ghana (ca. 560,999 km^2), yet both regions are similar in area and habitat—rainforest in the coastal lowlands, with savanna in the interior (White 1983) — and comparably well sampled.

Gabon is 43% smaller (ca. 267,667 km^2), and its scorpion fauna more poorly sampled, than neighboring Cameroon. However, Gabon includes six of the species recorded from Cameroon, and four of the six species endemic to the region (Table 1). This is unexpected, since Gabon incorporates less habitat diversity than Cameroon, comprising mostly lowland rainforest (White 1983). Future collecting efforts in the savannas of southern Gabon may increase the count.

The high species richness and endemism of Cameroon, Equatorial Guinea, and Gabon can be attributed to the greater number of silvicolous palaeoendemics (e.g., *O. lecomtei* and *Lychasioides amieti* Vachon, 1974), in turn resulting from prolonged climatic stability in the region. The Massif de l'Adamaoua, separating Cameroon from Nigeria, appears to represent a natural biogeographic boundary between the richer scorpion fauna inhabiting the rainforests of the Congo basin to the southeast, and the more depauperate scorpion fauna inhabiting the coastal rainforest-savanna mosaic to the west.

APPENDIX A
Specimens Examined

Babycurus buettneri. — West Africa, Dr Kirk: BMNH 1865.60 (holotype ♂ of *Rhoptrurus kirki*). CENTRAL AFRICAN REPUBLIC: Prefecture Sangha-Mbaéré, Parque National de Dzanga-Ndoki, Mabea Bay, 21.4 km 53° NE of Bayanga, at Camp 1, 03°02′01″N, 016°24′34″E, M. Burger, 5.v.2001: CAS (♀). GABON: Sibango Farm bei Gaboon, Büttner, 15.ix–20.x.1884: ZMB 4367 (holotype ♀); Prov. Ogooué-Maritime, Aire d'Exploit, Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 02°13′21″S, 010°24′21″E, 375 m, B. L. Fisher, 6–12.iii.2000, rainforest, bucket pitfall trap: CAS (2♂); Prov. Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 02°17′S, 010°29′49″E, 110 m, B. L. Fisher, 10.ii.2000, rainforest, ex rotten log: CAS (♀); Prov. Ogooué-Maritime, Reserve Monts Doudou, 25.2 km 304° NW Doussala, 02°13′36″S, 010°23′12″E, 375 m, M. Burger, 14–19.iii.2000, rainforest, between termite mound and tree trunk: AMC (♂); Prov. Ogooué-Maritime, SE of Gamba, on road to Vera, near pitfall trapline #3, 02°45′13″S, 010°06′41″E, M. Burger, vii.2001, in forest habitat: USNM (♀).

Babycurus centrurimorphus. — NW Madagaskar [dubious], J.M. Hildebrandt: ZMB 4307b (♀ lectotype), ZMB 4307a (♂, 3♀ paralectotypes).

Babycurus johnstonii. — CAMEROON: Rio del Rey [04°44′N, 008°39′E], near Old Calabar River, Cameroon-Nigeria border, H. H. Johnston: BMNH 1890.3.18.1–2 (lectotype ♀ and paralectotype ♀).

Babycurus melanicus. — GABON: Prov. Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 02°17′S, 010°29′49″E, 110 m, M. Burger, 3.iii.2000, rainforest, ex rotten log: ♀ (CAS); same data, except 'B. L. Fisher,

24.ii–3.iii.2000, rainforest, on ground': CAS (♀); Prov. Ogooué-Maritime, Aire d'Exploit, Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 02°13′21″S, 010°24′21″E, 375 m, B. L. Fisher, 6–12.iii.2000, rainforest, bucket pitfall trap: AMC (♀), CAS (subadult ♀); Prov. Ogooué-Maritime, Loango National Park, O. S. G. Pauwels, xi.2002: MRAC 213087 (2♀).

Babycurus neglectus. — GHANA: Kete Kratschi [Kete Krachi, 07°48′N, 000°01′W]: SMF RII/8873 (2♀ [not ♂, ♀]). TOGO: Atakpamé [07°38′N, 000°59′E]: SMF RII/6696 (♀).

Babycurus pictus. — KENYA: Athi Plains, G. W. Gregory: BMNH 1893.11.9.3 (holotype ♀).

Opisthacanthus africanus. — CENTRAL AFRICAN REPUBLIC: Prefecture Sangha-Mbaéré, Parque National de Dzanga-Ndoki, 38.6 km 173° S of Lidjombo, at Camp 3; 02°31′26″N, 016°03′12″E, M. Burger, 25.v.2001: CAS (♀). DEMOCRATIC REPUBLIC OF CONGO: Congo [06°04′S, 012°24′E], don. Gilson: MRAC 4552–4554 (♂, 2♀); Bas. Congo, Cattien, Delafaille, 1956: MRAC 88.080 (♀); Bas. Congo, Kimwenza [04°27′S, 015°17′E], R. P. Van Eyen, 1956: MRAC 85.570 (♀); Moyen Congo, Kimuenza, 04°28′S, 015°17′E, A. Bouillon, 1965: MRAC 128.436 (♂); Bas. Congo, rég. Weka, 05°43′S, 012°36′E, A. Marée, i.1949: MRAC 66.981 (♂); Equateur, Bas. Congo, riv. Bangu Bangu, km 53 route N Boma, 00°04′S, 019°12′E, J. Meulenbergh, 1964: MRAC 127.111 (♀); Kongo dia Venga, 05°26′S, 013°27′E, M. Bequaert, 19.vi.1951: MRAC 69.743 (subad. ♀); Bamania, 00°01′N, 018°19′E, R. P. Hulstaert, 20.iii.1956: MRAC 85.445 (♂); same data, except '21.viii.1957': MRAC 113.442 (♀); Bamba Kilenda [04°55′S, 015°29′E], Mme. Lepersonne, vii.1948: MRAC 61.382 (♂); Banana, 06°00′S, 012°24′E, Mesmaeckers, i.1952: MRAC 72.488 (♂); Basankusu, 01°14′N, 019°48′E, N. D. Bunderen, x.1951: MRAC 69.346 (subad. ♂); Bokuma, 00°06′S, 018°41′E, R. P. Lootens, 1.ii.1952: MRAC 72.528 (♂); same data, except 'vii.1952': MRAC 73.614 (♀); same data, except '1954': MRAC 80.864–80.865 (♂, ♀); Boma, 05°51′S, 013°03′E, L. Mesmaeckers, xii.1950: MRAC 68.924 (juv.); Bolobo, 02°10′S, 016°14′E, J. D. Viccars, 1956: MRAC 87.665 (♀); Coquilhatville [Mbandaka, 00°04′N, 018°16′E], Lang-Chapin Congo Exp., 19.v.1915: AMNH (♀); Kamangu [05°30′S, 018°06′E], H. Schouteden, 1941: MRAC 57.771 (♂); Kinshasa [04°20′S, 015°19′E], Lang-Chapin Congo Exp., 27.v.1915: AMNH (2♀); S. E. Kinshasa, 80 km de Moloundou, R. Brisson, vi.1970: MRAC 138.722 (2♂); Léopoldville [Kinshasa], 04°19′S, 015°19′E, Mme. Lepersonne, 1942: MRAC 57.667 (♀); Léopoldville, Stanley Pool [Pool Malebo, 04°17′S, 015°30′E], J. H. Camp, 30.ix.1893: USNM 27389 (5♂, 4♀, 2 juv.); Lukalela [01°03′S, 017°12′E], Breulheid, xi.1941: MRAC 57.728–57.730 (♂, 2♀); Lukolela [01°03′S, 017°12′E], Lang-Chapin Congo Exp., 21.v.1915: AMNH (♀); Lukengi, Kasoi [03°23′S, 018°03′E], Fontainas: MRAC 4677 (♀); Luki, 05°38′S, 013°04′E, A. van Olstein, 28.iv.1952: MRAC 72.704 (♀); Luki, Boma, 05°38′S, 013°04′E, Wagemans, 1957: MRAC 97.204–97.205 (♂, ♀); Camp de la Luki, 05°38′S, 013°04′E, Leprez: MRAC 130.815 (♀); Luozi, 04°57′S, 014°08′E, Bequaert and Schotte, 1951: MRAC 69.527 (juv. ♂); Mabali, 00°53′S, 018°07′E, G. Marlier, 1955: MRAC 85.441 (subad. ♀); Mayidi, 05°11′S, 015°09′E, R. P. van Eyen, 1952: MRAC 74.727–74.729 (♂, 2♀); Malela [04°20′S, 017°51′E], Lang-Chapin Congo Exp., 9.vii.1915: AMNH (3♂, 5♀, 2 subad. ♂, 3 subad. ♀, 15 juv.); Matadi, 05°49′S, 013°28′E, Courtois: MRAC 57.773 (♀); same data, except 'S. A. Coplac, 1920': MRAC 171.949 (♀); Mavuma,

05°05′S, 012°59′E, M. Bequaert, xi.1950: MRAC 68.934 (♀); Moanda, 05°56′S, 012°21′E, E. Dartevelle, 1947: MRAC 65.907 (♀); Wolter (C.F.M.L.) [04°49′S, 015°11′E], R. Close, 1954: MRAC 77.183 (♀). GABON: Prov. Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 02°17′S, 010°29′49″E, 110 m, B. L. Fisher, 25.ii–4.iii.2000, rainforest, bucket pitfall trap: AMC (♀); same data, except 'M. Burger, 3.iii.2000, rainforest, ex rotten log': CAS (♀); Prov. Ogooué-Maritime, E of Gamba, on road to Vera, trapline #5, 02°44′25″S, 010°06′41″E, M. Burger, 24.vii.2001, in forest habitat with stream nearby: USNM (♂).

Opisthacanthus lecomtei. — CAMEROON: Kamerun, West Africa, E. A. Ford: AMNH (♂, juv. ♂); British Cameroons, Sassé, near Buea [04°09′N, 009°14′E], ca. 3500 ft on slope of Mt. Cameroons, S. Tita, xii.1950: CAS (♂, ♀); same data, except 'iii.1951': CAS (♀); same data, except 'iv–v.1951': CAS (♀); Olounou, 02°49′N, 012°08′E, F. Puylaert, 11–19.ix.1971: MRAC 140.746 (subad. ♂); 10 mi W Bertoua [04°35′N, 013°41′E], 640 m, E. S. Ross and K. Lorenzen, 5.x.1966: CAS (♂, subad. ♂). EQUATO-RIAL GUINEA: Fernando Po [Bioko Island, 03°27′N, 008°41′E], Banapa, Ramon Persamon, vii.1968: MRAC 134.274 (♀). GABON: Prov. Ogooué-Maritime, Aire d'Exploit, Rationnelle de Faune des Monts Doudou, 24.5 km 303° WNW Doussala, 02°13′58″S, 010°23′53″E, 630 m, B. L. Fisher, 18.iii.2000, rainforest, sifted litter: AMC (♂).

Pandinus dictator. — West Africa, purchased Stevens: BMNH 1865.33 (paratype ♀). En face d'Irebou, rive Française ou fleuve Congo [Irebu, 00°37′S, 017°45′E, dubious], Nassent: MRAC 23.924 (♂). CAMEROON: 30 km E of Kribi [02°57′N, 009°55′E], on road to Yaoundé [03°52′N, 011°31′E], Vanderbilt Afr. Exped., 26.xi.1924: MCZ (2♂, 2♀, subad. ♂, 22 juv.); Kamerun, West Africa, E. A. Ford: AMNH 3427 (2♀); Kameroon, Finley McGrissett: AMNH 25505 (subad. ♀); Akandinga [Akanolinga, 03°46′N, 012°15′E], D. Thys v.d. Audenaerde, 28.x.1964: MRAC 127.802 (♀); Bipindi [03°05′N, 010°25′E], French Cameroon, S. E. Johnson: MCZ (6♀, juv. ♀); Efulén [02°46′N, 010°43′E], French Cameroon, Finley McGrissett, 1931–1932: AMNH (4♀, juv.); Ekoumdoum, Biba, 03°49′N, 011°32′E, D. Thys v.d. Audenaerde, 9.x.1964: MRAC 127.801 (2♂); Métet [02°58′N, 012°01′E], George Schwab: AMNH ex MCZ (♀), MCZ (3 ♀, subad. ♀); Mevo-Nkoulou, 03°47′N, 011°34′E, Thys v.d. Audernaerde, 22–28.iv.1973: MRAC 148.448 (♀); Lom et Kadié [Kadey], Miéri, Batouri, 04°15′N, 13°58′E, F. Puylaert, 26.i.1976: MRAC 148.189 (♀); Nkolmébang, 04°24′N, 011°25′E, D. Thys v.d. Audenaerde, 20.x.1964: MRAC 127.800 (5♂); Olounou, 02°49′N, 012°08′E, F. Puylaert, 11–19.ix.1971: MRAC 140.741 (♀); Sakbayémé [04°02′N, 010°34′E] par Edéa [03°48′N, 010°08′E], George Schwab: MCZ (♀). EQUATORIAL GUINEA: Micomeseng, 02°08′N, 010°37′E, M. Alderweireldt, vii.1989: MRAC 173.131 (♂); Fernando Po [Bioko Island, 03°27′N, 008°41′E], Capt. Birch: BMNH 1854.34 (holotype ♀); Fernando Po, St. Isabel, 03°45′N, 008°42′E, Ramon Persamon, vii.1968: MRAC 134.273 (♂). GABON: Omboué (Fernan Vaz) [01°34′S, 009°15′E], C. R. Aschemeier, Collins-Garner Congo Exp., 14.v.1917: USNM (♀); same data, except '30.vi.1917': USNM (♀); same data, except '7.vii.1917': USNM (♀); Oyem, 01°37′N, 011°35′E, J. Collot, 1966: MRAC 132.725 (♀); Prov. Ogooué-Maritime, Aire d'Exploit, Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 02°13′21″S, 010°24′21″E, 375 m, B. L. Fisher, 6–12.iii.2000, rain-forest, bucket pitfall trap: AMC (♀); Prov. Ogooué-Maritime, Aire d'Exploit, Rationnelle

de Faune des Monts Doudou, 24.5 km 303° WNW Doussala, 02°13'58"S, 010°23'53"E, 630 m, B. L. Fisher, 18.iii.2000, rainforest, sifted litter: AMC (2♂); Prov. Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 02°17'S, 010°29'49"E, 110 m, B. L. Fisher, 10.ii.2000, rainforest, on ground: CAS (♀); same data, except '24.ii–3.iii.2000, rainforest': CAS (4♂, 2♀, juv. ♀); same data, except '25.ii–4.iii.2000, rainforest, bucket pitfall trap': CAS (2♂, 2♀); same data, except 'M. Burger, 3.iii.2000, rainforest, ex rotten log': CAS (4 juv. ♂, juv. ♀); Prov. Ogooué-Maritime, Reserve Monts Doudou, 24.5 km 303° WNW Doussala, 02°14'S, 010°23'54"E, 630 m, B. L. Fisher, 18.iii.2000, rainforest, sifted litter: CAS (♂, subad. ♀, juv. ♀). No data: AMNH (juv.).

Pandinus gambiensis. — GAMBIA: Gambia, Captain Maloney: BMNH 1895.7 (holotype ♂). SENEGAL: USNM (2♂); Tonia Taba Gambia [Toniataba, 13°19'N, 013°35'W], D. E. Harvey, 14.vi.1966: USNM (2♂). No data: MCZ (2♀).

Pandinus imperator. — West Coast Africa, Dr G. A. Perkins: MCZ (♀). BENIN: 11°40'N, 002°50'E, near Djona on Alibory River, J. A. MacKallor, v.1964: USNM (juv. ♂); Ferme Founfoun à 1 km de Savacon [Savakon, 07°15'N, 002°04'E], D. Meirte, 30.iii.1997, sous bois mort: MRAC 208.379. CÔTE D'IVOIRE: Adiopo Doumé [05°20'N, 004°07'W], 17.viii.1966: MRAC 130.708 (♀); Appouessou, Forêt Classée Bossematie, Eco. Forest, 06°35'N, 003°28'W, pitfall, Station 2°, R. Jocqué and N. Séabé, 18.iii.1994: MRAC 205.479 (juv. ♀); same data, except 'Station 2B, 3.v.1994': MRAC 205.480 (juv. ♀); same data, except 'Station 2C, R. Jocqué and Tanoh, 9.iv.1995': MRAC 205.309 (juv. ♀); same data, except 'Station 2B': MRAC 205.310 (juv. ♀); Ivory Coast, Banco Forest [05°22'N, 004°03'W], J. Visser, ii.1989: SAMC C4509–4510 (2♀), SAMC C4508 (subad. ♂); Bingerville, 05°21'N, 003°54'W, J. Decelle, 1962: MRAC 123.726 (2♀); same data, except 'xii.1963': MRAC 126.978 (♂); Bouaké, 07°41'N, 005°02'W, P. M. Elsen, vi.1977: MRAC 160.472 (juv. ♀); same data, except 'v.1977': MRAC 160.474 (juv. ♂); Chaussée de Badika[ha], riv. Bandama blanc, 09°12'N, 005°10'W, G. Teugels, 22.viii.1985: MRAC 168.783 (juv. ♂); Danangoro, 07°11'N, 005°56'W, P. M. Elsen, iii.1977: MRAC 160.473 (juv. ♂); Flampleu, 07°17'N, 008°03'W, Verheyen and Thys v.d. Audenaerde, 20–24.vii.1966: MRAC 131.048–131.049 (2 juv. ♂); Kossou, 06°57'N, 004°58'W, R. Jocqué, 13.iv.1975: MRAC 160.528 (subad. ♂); same data, except '13.v.1975': MRAC 160.529 (2 juv. ♂); same data, except 'v.1975': MRAC 161.991 (2 juv. ♂, juv. ♀); Toyébli [06°37'N, 008°29'W], Verheyen and Thys v.d. Audenaerde, 2–3.viii.1966: MRAC 130.717 (7♂, 13♀); same data, except '29–30.viii.1966': MRAC 130.718 (11♂, 9♀); Village km 7 route Touépleu Liberia, 06°28'N, 008°38'W, Verheyen and Thys v.d. Audenaerde, 2.viii.1966: MRAC 130.719 (16♂, 6♀), MRAC 130.720 (20♂, 9♀). GHANA: Cape Coast [05°06'N, 001°14'W], Univ. Cape Coast Collection, Dr Jerry Boggs: AMNH (♂, ♀, 5 juv.); Cape Coast, 15.vi.1969: USNM (subad. ♂); Tafo [06°13'N, 000°22'W], residential area, in garden of bungalow, at base of dead plantain, excavated chambers in soil terrarium, R. G. Donald, iii–iv.1946: AMNH (2♂, juv.); Wegbe [07°07'N, 000°27'E], Togoland, W. Innes, 1899: SAMC 6353 (♀). LIBERIA: Colonization Society, J. O. Wilson: USNM 30467 (♂); Bell[e] Yella [07°23'N, 010°00'W], W. M. Mann, Smithsonian Institution-Firestone Expedition, iii.1940: USNM (♂); Dobli Island [06°53'N, 010°23'W], Bequaert: MCZ (♂); Ganta [05°38'N, 009°48'W], 1932: AMNH 32332 (2♀); Gibanga, Harvard Exped.: MCZ (3♂, 2♀, subad. ♂, juv. ♂); Gibi [06°40'N, 010°00'W], W. M. Mann, Smithsonian Institu-

tion-Firestone Expedition, 1940: USNM (♂, subad. ♂); Monrovia [06°18′N, 010°48′W]: MCZ (♂); Monrovia, 06°19′N, 010°48′W, W. G. Johnson, 1975: MRAC 147.335 (8♂, 5♀); Monrovia, R. N. Nilson, 29.vii.1963: CAS (2♂); Mt. Coffee [06°30′N, 010°36′W], O. F. Cook, 1896: USNM (5♂, ♀); Mt. Coffee, Rev. George P. Goll, 1899–1900: USNM (♀); Nimba County, Oldtown Gobonwea, 225 mi from Monrovia, 40 miles E Mt. Nimba [07°33′N, 008°37′W], Charles D. Miller III, at night, with aid of light, they frequent rocky outcrops in the bush, frequently come out during the day after heavy rains: AMNH (2♂, 2♀), USNM (4♂, 3♀); Yekepa Nimba, 07°35′N, 008°28′W, M. Louette and P. Rigaux, 15.iii.1980: MRAC 155.160 (♂); Zwedru (Tchien) [06°04′N, 008°08′W], Eastern Prov., J. J. Baldwin, Jr.: USNM 177246 (♂); Zwedru [06°01′N, 008°09′W], Jensen, 6.vi.1947: USNM (juv. ♀). NIGERIA: Ibadan, 07°14′N, 003°50′E, S. Afolabi Toye, ix.1968: MRAC 134.308 (♂, ♀); Jos, 09°55′N, 008°54′E, E. Bot Gwong, x–xii.1965: MRAC 130.639 (juv. ♂, 2 juv. ♀); Kaduna [10°36′N, 007°27′E], N Nigeria, W. McDonald, ii.1958: AMNH (♀); Kwara State, Iyale, 60 miles S Idah [07°39′N, 007°17′E], L. Dick, i.1970: AMNH (juv. ♀); Oloke Meji [07°25′N, 003°32′E], Ibadan: USNM (2♀); Plateau Province, Jos, 09°55′N, 008°54′E, Meussen and Bouguiaux, 7–26.iv.1963: MRAC 123.774 (juv. ♀). SIERRA LEONE: Freetown, Pepel Town, 08°30′N, 013°15′W, D. Olu-Pitt, iv.1977: MRAC 159.087 (juv. ♀); Pepel Town, 08°35′N, 013°03′W, D. Olu-Pitt, ix.1976: MRAC 148.502 (juv. ♂). TOGO: AMNH (♂, 3♀, juv.); Atakpamé, Kolekepe [Kolokopé], 07°28′N, 001°19′E, F. Puylaert, 26–31.viii.1969: MRAC 136.004 (♂); Badou, 07°37′N, 000°37′E, Dr W. Verheyen and coll., 17.vii.1968: MRAC 134.644 (♂); Bafilo, Aledje [Alédjo], 09°15′N, 001°12′E, F. Puylaert, 19.vii.1969: MRAC 136.007 (subad. ♀); Fazao [08°42′N, 000°46′E], F. Puylaert, 20–24.viii.1969: MRAC 200.957 ex 135.994 (♂, 2♀); Niamtougou, 09°46′N, 001°06′E, F. Puylaert, 21–24.vii.1969: MRAC 136.005 (2♂, ♀); Nanergou, 10°55′N, 000°09′E, Dr W. Verheyen and coll., 17.viii.1968: MRAC 134.642 (7♂, 11♀); Togoville, 06°14′N, 001°29′E, F. Puylaert, 11–17.ix.1969: MRAC 136.006 (♂), MRAC 200.958 ex 135.995 (♀), MRAC 136.008 (2 juv. ♂, 2 juv. ♀). No data: AMNH (2♂).

LITERATURE CITED

BACELAR, A. 1950. Notas acerca dos aracnideos do ultramar português. Jta. Invest. Colon., Lisboa 17:1–24.

BEAUVOIS, A.-M.-F.-J. Palisot De. 1805. Insectes recueillis en Afrique et en Amérique, dans les Royaumes d'Oware et de Benin, à Saint-Domingue et dans les États-Unis, pendant les années 1786–1787. De l'Imprimerie de Fain et Compagne, Paris. 276 pp.

BECKER, L. 1880. Études sur les scorpions. Ann. Soc. Entomol. Belg. 24:134–145.

BELFIELD, W. 1956. A preliminary check list of the West African scorpions and key for their identification. J. West Afr. Sci. Assoc. 2:41–47.

BIRULA, A. A. 1910. Über *Scorpio maurus* Linné und seine Unterarten. Horae Soc. Entomol. Rossicae 35:115–192.

———. 1913. Arachnologische Beiträge II–IV. (II. Über einige *Scorpiops*-Arten von dem südabhange des Himalaya. III. Über *Pandinus* (*Pandinops*) *peelei* Poc. und seine Verwandten. IV. Über das Vorkommen der gemeinen Perlmutterzecke (*Dermacentor reticulatus* [Fabr.] - Ixodidae) in den mittleren Tellen Westrusslands). Rev. Russ. Entomol. 13:416–423.

———. 1914. Miscellanea scorpiologica. X. Bemerkungen über die von S. F. Swatosch in Britisch Ost-Afrika gesammelten Skorpionen-Arten. Ann. Mus. Zool. Acad. Sci., St. Petersburg 19:114–124.

———. 1915a. A general list of the scorpions of British East Africa. Sci. Res. Zool. Exp. British E. Africa and Uganda made by Prof. V. Dogiel and I. Sokolow 1:1–31.

————. 1915b. Arachnologische Beiträge. V. Weitere Bemerkungen über die Skorpionen-Fauna Britisch Ost-Afrikas. Rev. Russ. Entomol. 15:50–65.

————. 1927. Wissenschaftliche Ergebnisse der mit Unterstützung der Akademie der Wissenschaften in Wien aus der Erbschaft Treitl von F. Werner unternommenen zoologischen Expedition nach dem Anglo-Aegyptischen Sudan (Kordofan) 1914. XXV. Skorpione. Denkschr. Akad. Wiss., Wien 101:79–88.

BORELLI, A. 1911. Scorpioni raccolti da Leonardo Fea nell'Africa occidentale. Ann. Mus. Civ. Stor. Nat. Genova (3) 45:8–13.

————. 1913. Scorpioni raccolti dal Prof. F. Silvestri nell'Africa occidentale. Boll. Lab. Zool. Portici 7:218–220.

————. 1925. Di alcuni scorpioni della Somalia Italiana. Ann. Mus. Civ. Stor. Nat. Genova 51:316–326.

BÜCHERL, W. 1964. Distribução geográfica dos Aracnóides peçonhentos temíveis. Mém. Inst. Butantan 31:55–66.

CASPER, G. S. 1985. Prey capture and stinging behavior in the Emperor scorpion, *Pandinus imperator* (Koch) (Scorpiones, Scorpionidae). J. Arachnol. 13:277–283.

COPELAND, R. J. N. 1990. Notes on the breeding of Imperial Scorpions (*Pandinus imperator*). Browse Press. 28 pp.

COUZIJN, H. W. C. 1976. Functional anatomy of the walking-legs of Scorpionida with remarks on terminology and homologization of leg segments. Neth. J. Zool. 26:453–501.

DUPRÉ, G. 1990a. Notes sur la répartition des scorpions du Togo. Arachnides 6:8–10.

————. 1990b. Le point sur l'élevage de *Pandinus* (*Pandinus*) *imperator* C. L. Koch 1842 (Scorpionida, Scorpionidae). Arachnides 7:9–13.

EL-HENNAWY, H. K. 1992. A catalogue of the scorpions described from the Arab countries (1758–1990) (Arachnida: Scorpionida). Serket 2:95–153.

FAGE, L. 1929. Origine probable et différentiation de la faune des scorpions de Madagascar. C. R. Soc. Biogéogr. Paris 49:72–76.

FAGE, L. AND E. SIMON. 1936. Mission scientifique de l'Omo. Arachnida. III. Pedipalpi, Scorpiones, Solifuga et Araneae (1ʳᵉ partie). Mém. Mus. Natn. Hist. Nat., Paris 4:293–340.

FET, V. 2000a. Family Ischnuridae. Pp. 383–408 *in* Catalog of the Scorpions of the World (1758–1998), V. Fet, W. D. Sissom, G. Lowe and M. E. Braunwalder. New York Entomol. Soc., New York.

————. 2000b. Family Scorpionidae. Pp. 427–495 *in* Catalog of the Scorpions of the World (1758–1998), V. Fet, W. D. Sissom, G. Lowe and M. E. Braunwalder. New York Entomol. Soc., New York.

FET, V. AND G. LOWE. 2000. Family Buthidae. Pp. 54–286 *in* Catalog of the Scorpions of the World (1758–1998), V. Fet, W. D. Sissom, G. Lowe and M. E. Braunwalder. New York Entomol. Soc., New York.

FET, V., W. D. SISSOM, G. LOWE, AND M. E. BRAUNWALDER. 2000. Catalog of the Scorpions of the World (1758–1998). New York Entomol. Soc., New York. 690 pp.

FRADE, F. 1947. Escorpiões, Solifugos e Pedipalpos da Guinéa Portuguesa. Jta. Invest. Colon., Lisboa 3:5–18.

FRANCKE, O. F. 1974. Nota sobre los géneros *Opisthacanthus* Peters y *Nepabellus* nom. nov. (Scorpionida, Scorpionidae) e informe sobre el hallazgo de *O. lepturus* el la Isla del Coco, Costa Rica. Brenesia 4:31–35.

GARNIER, G. 1973. Mise en évidence de deux races écologiques chez *Pandinus imperator* (C. L. Koch, 1842) de Côte d'Ivoire (Scorpionidae, Scorpioninae). C. R. Acad. Sci. Paris (D) 277:1813–1816.

————. 1974. Elevage en laboratoire de *Pandinus imperator* (C. L. Koch, 1842) (Scorpionidae—Scorpioninae). Bull. Soc. Zool. France 99:693–699.

GARNIER, G. AND R. STOCKMANN. 1972. Etude comparative de la pariade chez différentes espèces de scorpions et chez *Pandinus imperator*. Ann. Univ. Abidjan (E) 5:475–497.

————. 1971 [1973]. Comportement de la reproduction chez le scorpion *Pandinus imperator*. Pp. 13–21 *in* Proc. Arachnol. Congr. Intern. V, Brno.

GEERAERTS, J. 1953. Studie over gift en antigift in verband met de schorpioenen van Belgisch-Kongo. Bull. Agric. Congo Belge 44:1055–1084.

GILTAY, L. 1929. Voyage au Congo de S. A. R. le Prince Léopold Belgique (1925). Arachnides. 1. Scorpions. 2. Araignées. Rev. Zool. Bot. Afr. 17:17–18.

GUÉRIN-MÉNEVILLE, F. E. [1843]. Arachnides. Pp. 5–20 *in* Iconographie du Règne animal de G. Cuvier, ou représentation d'après nature de l'une des espèces les plus remarquables et souvent non encore figurées, de chaque genre d'animaux, 3. Imprimerie de Fain et Thunot, Paris.

HEWITT, J. 1912. Records and descriptions of some little known South African scorpions. Rec. Albany Mus. 2:300–311.

HJELLE, J. T. 1990. Anatomy and morphology. Pp. 9–63 *in* The Biology of Scorpions, G. A. Polis, ed. Stanford Univ. Press, Stanford, California.

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE. 1985. International Code of Zoological Nomenclature. Third edition. Univ. California Press, Berkeley. 338 pp.

INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE. 1994. Analyses of proposals to amend the CITES appendices. Inclusion of Emperor Scorpions *Pandinus dictator*, *P. gambiensis* and *P. imperator* in appendix II. Ghana. I.U.C.N. Doc. 9. 47. 63–65:186–188.

KARSCH, F. 1879. West-afrikanische Arachniden gesammelt von Herrn Stabsarzt Dr Falkenstein. Zeitschr. Ges. Nat. Berlin (3) 4:329–373.

———. 1884. Über einige neue und minder bekannte Arthropoden des Bremer Museums. Abh. Naturw. Ver. Bremen 9:65–71.

———. 1886. Skorpionologische Beitrage (I. Über einen sizilianischen Skorpion.—II. Übersicht der Gruppe Buthina (Androctonina).—III. Über einen neuen *Opisthacanthus* (Peters) Thor). Berliner Entomol. Zeitschr. 30:75–79.

KÄSTNER, A. 1941. 1. Ordnung der Arachnida: Scorpiones. Pp. 117–240 *in* Handbuch der Zoologie, 3, T. Krumbach, ed. Walter de Gruyter Verlag, Berlin.

KOCH, C. L. 1836. Die Arachniden. C. H. Zeh Buchhandlung, Nürnberg. 3:17–104.

———. 1841. Die Arachniden. C. H. Zeh Buchhandlung, Nürnberg. 9:1–11.

———. 1850. Scorpionen. Pp. 86–92 *in* Übersicht des Arachnidensystems, 5. C. H. Zeh Buchhandlung, Nürnberg.

KOVAŘÍK, F. 1992. A check list of scorpions (Arachnida: Scorpiones) in the collections of the zoological department, National Museum in Prague. Acta Soc. Zool. Bohem. 56: 181–186.

———. 1997. A check-list of scorpions (Arachnida) in the collection of the Hungarian Natural History Museum, Budapest. Ann. Hist.-Nat. Mus. Natn. Hungarici 89:177–185.

———. 1998. Štíři (Scorpiones). Madagaskar, Jihlava. 175 pp.

———. 2000. Revision of *Babycurus* with descriptions of three new species (Scorpiones: Buthidae). Acta Soc. Zool. Bohem. 64:235–265.

KRAEPELIN, K. 1891. Revision der Skorpione. I. Die Familie der Androctonidae. Jahrb. Hamburg wiss. Anst. 8:1–144.

———. 1894. Revision der Scorpione. II. Scorpionidae und Bothriuridae. Jahrb. Hamburg wiss. Anst. 11:1–248.

———. 1895. Nachtrag zu Theil I der Revision der Scorpione. Jahrb. Hamburg wiss. Anst. 12:73–96.

———. 1896. Neue und weniger bekannte Scorpione. Jahrb. Hamburg wiss. Anst. 13:119–146.

———. 1898. Die Skorpione Ost-Afrikas. Pp. 1–5 *in* Die Thierwelt Ost-Afrikas und der Nachbargebiete, 4, Wirbellose Thiere, K. Moebius, ed. Reimer, Berlin.

———. 1899. Scorpiones und Pedipalpi. Pp. 1–265 *in* Das Tierreich, 8, F. Dahl, ed. R. Friedländer und Sohn, Berlin.

———. 1901. Catalogue des scorpions des collections du Muséum d'Histoire Naturelle de Paris. Bull. Mus. Natn. Hist. Nat., Paris 7:263–274.

———. 1911. Neue Beiträge zur Systematik der Gliederspinnen. Jahrb. Hamburg wiss. Anst. 28:59–107.

———. 1913. Neue Beiträge zur Systematik der Gliederspinnen. III. A. Bemerkungen zur Skorpionenfauna Indiens. B. Die Skorpione, Pedipalpen und Solifugen Deutsch-Ostafrikas. Jahrb. Hamburg wiss. Anst. 30:123–196.

———. 1929. Skorpione, Pedipalpen und Solifugen der zweiten Deutschen Zentral-Afrika-Expedition 1910–1911. Abh. Naturw. Ver. Hamburg 22:85–91.

KRAPF, D. 1988. Skorpione II. Fortpflanzung, Wachstum und Haltung. Herpetofauna (Weinstadt) 56:24–33.

KRIESCH, M. 1994. Note sur la sociabilité du scorpion *Pandinus imperator* (C. L. Koch, 1842). Arachnides 21:9.

LAMORAL, B. H. 1979. The scorpions of Namibia (Arachnida: Scorpionida). Ann. Natal Mus. 23:497–784.

————. 1980. A reappraisal of the suprageneric classification of recent scorpions and their zoogeography. Pp. 439–444 in Verhandlungen 8 Internationaler Arachnologen Kongress, Universität für Bodenkultur Wien, 7–12 Juli 1980, J. Gruber, ed. H. Egermann, Vienna.

LAMORAL, B. H. AND S. C. Reynders. 1975. A catalogue of the scorpions described from the Ethiopian faunal region up to December 1973. Ann. Natal Mus. 22:489–576.

LAMPE, E. 1917. Katalog der Skorpione, Pedipalpen und Solifugen des Naturhistorischen Museums der Residenzstadt Wiesbaden. Jahrb. Ver. Nat. Wiesbaden 70:185–203.

LARROUY, G., M. C. SIGNOREL, AND Y. CAMBEFORT. 1973. Comportement en captivité de *Pandinus imperator* C. L. Koch et connaissance des jeunes. Bull. Soc. Hist. Nat. Toulouse 109:346–350.

LINNEAUS, C. (C. VON LINNÉ) 1758. Scorpions. Pp. 624–625 in Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Ed. 10. Laurentii Salvii, Holmiae (Stockholm).

LÖNNBERG, E. 1897. Skorpioner och pedipalper i Upsala Universitets Zoologiska Museum. Ent. Tidskr. 18:175–192.

LOURENÇO, W. R. 1979. Liste des espèces et sous-espèces appartenant au genre *Opisthacanthus* Peters, 1861 (Scorpiones, Scorpionidae). Rev. nordest. Biol. 2:27–36.

————. 1982a. Désignation d'un néotype pour *Opisthacanthus lecomtei* (Lucas, 1858) (Scorpiones, Scorpionidae). Bull. Mus. Natn. Hist. Nat., Paris (4) 3:1163–1168.

————. 1982b. Redécouverte de l'holotype d'*Opisthacanthus africanus* Simon 1876 (Scorpiones, Scorpionidae). Rev. arachnol. 3:147–153.

————. 1986. Les scorpions de la station écologique de Lamto (Côte d'Ivoire). Bull. Mus. Natn. Hist. Nat., Paris (Zool. Biol. Écol. anim.) 8:199–208.

————. 1987. Révision systématique des scorpions du genre *Opisthacanthus* (Scorpiones, Ischnuridae). Bull. Mus. Natn. Hist. Nat., Paris (Zool. Biol. Écol. anim.) 9:887–931.

————. 1991. *Opisthacanthus*, genre gondwanien défini comme groupe naturel. Caractérisation des sous-genres et des groupes d'espèces (Arachnida, Scorpiones, Ischnuridae). Iheringia, Sér. zool. 71:5–42.

————. 1995. Nouvelles considérations sur la classification et la biogéographie des *Opisthacanthus* néotropicaux (Scorpiones, Ischnuridae). Biogeographica 71:75–82.

————. 1996. Faune de Madagascar. 87. Scorpions (Chelicerata, Scorpiones). Muséum national d'Histoire naturelle, Paris. 102 pp.

LOURENÇO, W. R. AND J. L. Cloudsley-Thompson. 1996. Recognition and distribution of the scorpions of the genus *Pandinus* Thorell, 1876 accorded protection by the Washington convention. Biogeographica 72:133–143.

————. 1999. Variation in energy spent on reproduction between forest and savanna populations of *Pandinus imperator* (Koch) (Scorpiones, Scorpionidae) in the Ivory Coast. Bull. Br. Arachnol. Soc. 11:136–138.

LOWE, G. 2000. A new species of *Babycurus* (Scorpiones: Buthidae) from northern Oman. Ent. News 111:185–192.

LUCAS, H. 1858. Arachnides. In Histoire naturelle des Insectes et des Arachnides recueillis pendant un voyage fait au Gabon en 1856 et en 1857, J. Thomson. Archives Entomologiques ou Recueil Contenant des Illustrations d'Insectes Nouveaux ou Rares, Paris 2:428–430.

MAHSBERG, D. 1990. Brood care and family cohesion in the tropical scorpion *Pandinus imperator* (Koch) (Scorpiones: Scorpionidae). Acta Zool. Fennica 190:267–272.

MAHSBERG, D., R. LIPPE, AND S. KALLAS. 1999. Skorpione. Natur und Tier Verlag, Münster. 160 pp.

MONTAMBAUX, P. 1996. Maintenance en captivité de *Pandinus imperator*. Reptile Mag. 5:15–16.

MORITZ, M. AND S.-C. FISCHER. 1980. Die Typen der Arachniden-Sammlung des Zoologisches Museums Berlin. III. Scorpiones. Mitt. Zool. Mus. Berlin 2:309–326.

NENILIN, A. B. AND V. FET. 1992. [Zoogeographical analysis of the world scorpion fauna (Arachnida: Scorpiones)]. Arthropoda Selecta 1:3–31. [In Russian]

NEWLANDS, G. 1973. Zoogeographical factors involved in the trans-Atlantic dispersal pattern of the genus *Opisthacanthus* Peters (Arachnida; Scorpionidae). Ann. Transv. Mus. 28:91–101.

————. 1978. Arachnida (except Acari). Pp. 685–702 in Biogeography and Ecology of Southern Africa, M. J. A. Werger, ed. W. Junk, The Hague.

————. 1987. Scorpions. De Jager-HAUM, Pretoria. 40 pp.

PAVESI, P. 1895. Aracnidi raccolti ne Paese dei Somali dall'ing L. Bricchetti-Robecchi. Boll. Sci. 17:37–46.

————. 1897. Studi sugli Aracnidi Africani. IX. Aracnidi Somali e Galla raccolti da Don Eugenio dei Principi Ruspoli. Ann. Mus. Civ. Stor. Nat. Genova (2) 28:151–188.

PAVLOVSKY, E. N. 1924. On the morphology of the male genital apparatus in scorpions. Trans. Soc. Nat. Leningrad 53:17–86.

———. 1925. Zur Morphologie des weiblichen Genitalapparatus und zur Embryologie der Skorpione. Ann. Mus. Acad. Sci. Zool. USSR 26: 137–205.

POCOCK, R. I. 1888. On the African specimens of the genus *Scorpio* (Linn.), contained in the collection of the British Museum. Ann. Mag. Nat. Hist. (6) 2:245–255.

———. 1890. A revision of the genera of scorpions of the family Buthidae, with descriptions of some South-African species. Proc. Zool. Soc. 1890:114–141.

———. 1893. Notes on the classification of scorpions, followed by some observations on synonymy, with descriptions of new genera and species. Ann. Mag. Nat. Hist. (6) 12:303–330.

———. 1896. On the scorpions, centipedes and millipedes obtained by Dr. Gregory on his expedition to Mount Kenia, East Africa. Ann. Mag. Nat. Hist. (6) 17:425–444.

———. 1898. The Arachnida from the regions of Lake Nyasa and Tanganyika contained in the collection of the British Museum. Ann. Mag. Nat. Hist. (7) 2:429–448.

———. 1899. On the scorpions, pedipalps and spiders from Tropical West Africa represented in the collection of the British Museum. Proc. Zool. Soc. London, 1899:833–885.

POLIS, G. A. AND W. R. LOURENÇO. 1986. Sociality among scorpions. Pp. 111–115 *in* Actas 10th Congr. Int. Aracnol. Jaca, España.

PRENDINI, L. 2001. Further additions to the scorpion fauna of Trinidad and Tobago. J. Arachnol. 29:173–188.

PROBST, P. J. 1972. Zur Fortpflanzungsbiologie und zur Entwicklung der Giftdrüsen beim Skorpion *Isometrus maculatus* (De Geer, 1778) (Scorpiones: Buthidae). Acta Tropica 29:1–87.

———. 1973. A review of the scorpions of East Africa with special regard to Kenya and Tanzania. Acta Tropica, 30:312–335.

PROST, A. 1982. L'identification des scorpions de Haute-Volta. Notes Doc. Volta., Ouagadougou 13:4–10.

ROEWER, C. F. 1943. Über eine neuerworbene Sammlung von Skorpionen des Natur-Museums Senckenberg. Senckenbergiana 26:205–244.

———. 1952. Solifuga, Opiliones, Pedipalpi und Scorpiones (Arachnoidea). Explor. Parc Nat. Upemba, Mission G. F. de Witte 5:1–36.

SCHIEJOK, H. 1997. Einige Gedanken zur Haltung von *Pandinus imperator* (C. L. Koch, 1842). Skorpion-News 2:39–43.

SIMON, E. 1872. Études sur les Scorpions. Rev. Mag. Zool. (2) 23:51–59, 97–101.

———. 1876. Étude sur les Arachnides du Congo. Bull. Soc. Zool. France 1:215–224.

———. 1903. Arachnides de la Guinée espagnole. Mem. Soc. Espan. Hist. Nat., Madrid 1:65–124.

———. 1904. Étude sur les Arachnides recueillis au cours de la mission du Bourg-de-Bozas en Afrique. Bull. Mus. Natn. Hist. Nat, Paris 7:442–448.

SISSOM, W. D. 1990. Systematics, biogeography and paleontology. Pp. 64–160 *in* The Biology of Scorpions, G. A. Polis, ed. Stanford Univ. Press, Stanford, California.

———. 1994. Descriptions of new and poorly known scorpions of Yemen (Scorpiones: Buthidae, Diplocentridae, Scorpionidae). Fauna of Saudi Arabia 14:3–39.

SMITHE, F. B. 1974. Naturalist's Color Guide Supplement. The American Museum of Natural History, New York. 229 pp.

———. 1975. Naturalist's Color Guide. The American Museum of Natural History, New York, unpaginated.

———. 1981. Naturalist's Color Guide. Part III. The American Museum of Natural History, New York. 37 pp.

STAHNKE, H. L. 1970. Scorpion nomenclature and mensuration. Ent. News 81:297–316.

———. 1972. A key to the genera of Buthidae (Scorpionida). Ent. News 83:121–133.

STRAND, E. 1916. Über einige Arachniden aus Buea in Kamerun. Arch. Natur. 81A:139–149.

STRINATI, P. 1960. La faune actuelle de trois grottes d'Afrique Équatoriale Française. Ann. Spéléol. 15:533–538.

TAKASHIMA, H. 1952. [Miscellaneous notes on scorpions]. Acta Arachnol. 13:26–36. [In Japanese].

THORELL, T. 1876. Études Scorpiologiques. Atti Soc. Ital. Sci. Nat. 19:75–272.

———. 1893. Scorpiones exotici R. Musei Historiae Naturalis Florentini. Boll. Soc. Entomol. Ital. 25:356–387.

TOYE, S. A. 1970. Some aspects of the biology of two common species of Nigerian scorpions. J. Zool. London 162:1–9.

VACHON, M. 1940a. Voyage en A. O. F. de L. Berland et J. Millot. Scorpions. V. Bull. Soc. Zool. France 65:170–184.

———. 1940b. Sur la systématique des scorpions. Mém. Mus. Natn. Hist. Nat, Paris 13:241–260.

———. 1952. La réserve naturelle intégrale du Mt. Nimba I. Scorpions. Mission M. Lamotte en Guinée (1942). Mém. I. F. A. N., Dakar 19:9–15.

———. 1967. Le grand scorpion du Sénégal: *Pandinus gambiensis* Pocock, 1899 doit être considéré comme une véritable espèce et non comme une sous-espèce de *Pandinus imperator* C. L. Koch, 1842. Bull. I. F. A. N., Dakar (A) 29:1534–1537.

———. 1968 [1970]. The distribution of scorpions in western Africa (Arachnida Scorpiones). Pp. 9–10 *in* West African International Atlas.

———. 1973 [1974]. Étude des caractères utilisés pour classer les familles et les genres de scorpions (Arachnides). 1. La trichobothriotaxie en arachnologie. Sigles trichobothriaux et types de trichobothriotaxie chez les scorpions. Bull. Mus. Natn. Hist. Nat., Paris (3) 140:857–958.

———. 1980. Remarques biogéographiques sur la faune des scorpions de Madagascar à propos de l'utilisation de caractères trichobothriotaxiques permettant la distinction des genres *Odonturus* Karsch, 1879 et *Tityobuthus* Pocock, 1893. Pp. 217–224 *in* C. R. 5e Colloque Arachnol. Barcelona, 1979.

WARBURG, M. R. AND G. A. POLIS. 1990. Behavioral responses, rhythms and activity patterns. Pp. 224–246 *in* The Biology of Scorpions, G. A. Polis, ed. Stanford Univ. Press, Stanford, California.

WERNER, F. 1902. Die Scorpione, Pedipalpen und Solifugen in der zoologisch-vergleichend -anatomischen Sammlung der Universität Wien. Verh. zool.-bot. Ges. Wien 52:595–608.

———. 1916. Über einige Skorpione und Gliederspinnen des Naturhistorischen Museums in Wiesbaden. Jahrb. Ver. Wiesbaden 69:79–97.

———. 1934. Scorpiones, Pedipalpi. Pp. 1–316 *in* Klassen und Ordnungen des Tierreichs, 5, IV, 8, Lief. 1–2, H. G. Bronn, ed. Akademische Verlagsgesellschaft, Leipzig.

———. 1936. Neu-Eingänge von Skorpionen im Zoologischen Museum in Hamburg. Festschr. Embrik Strand, Riga 2:171–193.

WHITE, F. 1983. Vegetation map of Africa. Unesco/AETFAT/UNSO, Paris.

Diversity Patterns of Ants (Hymenoptera: Formicidae) Along an Elevational Gradient on Monts Doudou in Southwestern Gabon

Brian L. Fisher

Department of Entomology, California Academy of Sciences
Golden Gate Park, San Francisco, California 94118-4599
email: bfisher@calacademy.org

Ants were collected at three elevations (110 m, 375 m, 640 m) using the following methods: litter sifting, sweeping, beating, yellow pan traps, pitfall, Malaise traps, and hand collecting. A total of 310 species in 56 genera were recorded from Monts Doudou. This is the highest species richness of ants yet recorded in Africa. Species richness was relatively constant along the elevational gradient surveyed (210 species at 110 m and 206 species at 375 m and 640 m). Comparison of ant species turnover along the gradient did not show evidence of variation with respect to elevation. Based on one well-studied group, Dacetonini, most species have previously been recorded from Gabon and have broad distribution ranges across the western Congo Basin. Leaf litter methods captured the greatest number of species followed by sweeping, beating, and general collecting. Yellow pan, pitfall, and Malaise traps collected the fewest species. Sweeping is rarely conducted in ant inventories, but these results suggest it should be included in the Afrotropical region.

Résumé

Les fourmis ont été récoltées à trois altitudes (110 m, 375 m, et 640 m) en utilisant les méthodes suivantes: tamisage de litières, filet de fauchage, pièges bac jaunes, trous pièges, parapluie japonais, piège Malaise et récoltes à vue. Un total de 310 espèces dans 56 genres sont mentionnées des monts Doudou. Ceci représente le nombre d'espèces de fourmis le plus élevé en Afrique. Les nombres d'espèces sont relativement constants sur tout le gradient d'élévations étudiées (210 espèces pour le site à 110 m, 206 espèces pour les sites à 375 et 640 m). La comparaison de la succession des espèces le long du gradient n'a pas mis en évidence de variation liée à l'altitude. A partir d'un groupe très connu, Dacetonini, la plupart des espèces ont déjà été mentionnées au Gabon et ont une vaste distribution le long de l'ouest du bassin du Congo. La méthode de tamisage de litières a permis de capturer le plus grand nombre d'espèces suivie par le filet de fauchage, le parapluie japonais et la récolte à vue. Les pièges bac jaunes, trous pièges et pièges Malaise ont permis de récolter un plus faible nombre d'espèces. Le filet de fauchage est rarement utilisé pour la récolte des fourmis mais ces résultats suggèrent que cette méthode devrait être davantage utilisée.

Introduction

Systematics provides an essential foundation for understanding, conserving, and using biodiversity in the Congo Basin. Yet for many groups of organisms we lack even such basic information as the identity and numbers of species found in the region. This is espe-

cially true for hyperdiverse groups of Arthropods such as ants (Hymenoptera: Formicidae), for which even approximate estimates of species richness and distribution patterns remain difficult to ascertain (Robertson 2000a).

Ants are an especially diverse and ecologically important group whose social behavior and ecological dominance have been the subjects of intense biological study (Hölldobler and Wilson 1990). Despite this long history of research and their ecological importance, considerable gaps remain in our understanding of the African ant fauna (Robertson 2000a and included references). For example, the species-level taxonomy of driver ants (*Aenictus* and *Dorylus*) is fragmentary and out-of-date, despite their spectacular predatory and nomadic behavior and the evidence that certain "keystone" species exert a major influence on the composition of forest arthropod communities (Franks and Bossert 1983; Gotwald 1995). A more complete inventory of African ants is essential to advance understanding of their ecology, evolution, and behavior, and to take full advantage of their demonstrated value in conservation priority setting, biomonitoring, and biological control (Agosti et al. 2000).

Quantitative sampling of ants has been conducted in Ghana (Belshaw and Bolton 1994), South Africa (Majer and de Kock 1994), Tanzania (Robertson 1999), and Namibia (Robertson 2000b). In this paper, I report the first quantitative survey of ants in the Congo Basin. Inventories were conducted along an elevational gradient at three sites: 110 m, 375 m, and 640 m on Monts Doudou, in southwestern Gabon. Information is presented on the species composition along the gradient and the relative efficiency of methods to capture ants.

METHODS

Study sites

Ants were intensively surveyed from 24 February to 21 March 2000 at three principal localities along an elevational gradient on Monts Doudou. The reserve is located in southwestern Gabon in the Province de Ogooué-Maritime. The inventories were conducted at the following sites and habitats within the Reserve:

Camp 1. Reserve de Faune de la Moukalaba-Douboua, 12.2 km 305° NW Doussala, 40.2 km 324° NW Mourindi, 2°17.00′S, 10°29.83′E, 110 m, lowland rainforest, 24 February–4 March 2000.

Camp 2. Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 52.1 km 321° NW Mourindi, 2°13.35′S, 10°24.35′E, elevation zone 350–425 m, with principal collection conducted at 375 m; mid-elevation rainforest, 5 March–12 March 2000.

Camp 3. Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 25.2 km 304° NW Doussala, 52.6 km 321° NW Mourindi, 2°13.63′S, 10°23.67′E, elevation zone 585–660 m, with principal collections conducted at 640 m; mid-elevation rainforest, 14 March–21 March 2000.

In addition, a second low elevation site (110 m) was visited on February 29, 2000 (Reserve de Faune de la Moukalaba-Douboua, 10.8 km 214° SW Doussala 2°25.4′S, 10°32.7′E). This site was located 16.4 km SSE of Camp 1. In this paper, Camp 1 along with this additional 110-meter site is referred to as the 110-meter site, Camp 2 as the 375-meter site, and Camp 3 as the 640-meter site.

The habitat of all sites was lowland rainforest. The 110-meter sites had been selectively logged until 1992. Camp 2 and Camp 3 did not show any signs of previous logging.

During a 10-day reconnaissance in the region before the expedition, the 660 m summit near Camp 3 was the highest point encountered on Monts Doudou.

Survey methods

In each elevational zone, ants were surveyed using seven principal methods: leaf litter sifting, pitfall, yellow pan, beating, sweeping, Malaise, and general (hand) collecting methods. Simon van Noort conducted the yellow pan, sweeping, and Malaise traps as part of his study on Ichneumonidae. [See Chapter on Ichneumonid (Hymenoptera) diversity, by Simon van Noort in this volume for additional details.] These methods are described below:

(1) Leaf litter sifting (L). Invertebrates were extracted from samples of leaf litter (leaf mold, rotten wood) using a modified form of the Winkler extractor (see Fig. 2 in Fisher 1998). The leaf litter samples involved establishing 50, 1 m^2 plots, separated by 5 m intervals, along a 250-meter transect line. The leaf litter inside each plot was collected and sifted through a wire sieve with square holes of 1 cm × 1 cm. Before sifting, the material was chopped with a machete to disturb ant nests in small twigs and decayed logs. Ants and other invertebrates were extracted from the sifted litter during a 48-hour period in mini-Winkler sacks (for a detailed discussion of the mini-Winkler method, see Fisher 1998, 1999). At each elevation zone, two transects were conducted, each with 50 litter samples. At 110 m, the second litter transect was located 16.4 km from the first. At the 375 m and 640 m camps, the litter transects were placed less than 1 km apart.

(2) Beating low vegetation (B). Along the 50-sample leaf litter transect, 25 beating stations were established 10 m apart. Ants on low vegetation and arboreal ants were sampled by holding a stretched 1 m × 1 m white nylon platform below the undergrowth and beating the trunk or a branch three times with a stick. The dislodged ants were aspirated and placed in ethanol. This process was repeated six times for each of the 25 beating samples. Therefore each beating sample consisted of six different plant subsamples, each beaten three times with a stick. The six beating subsamples were taken within a 5 m radius of the beating station along the leaf litter transect.

(3) Pitfall traps (P). In each elevational zone, three pitfall transects with 11 buckets per transect were surveyed each morning for ants. The pitfall traps (275 mm deep, 285 mm top internal diameter, 220 mm bottom internal diameter) were sunk with their rims flush with ground level. Pitfall trap lines were set for eight days at Camp 1 and for seven days each at Camps II and III. (See detailed description in Burger et al. this volume).

(4) Malaise traps (M). Four Malaise traps were deployed in each elevation zone and serviced each day for a period of seven days. [See Chapter on Ichneumonid (Hymenoptera) diversity, by Simon van Noort in this volume for additional details.]

(5) Yellow pan traps (Y). A transect consisting of 25 stations spaced at 5 m intervals was laid out at each sampled elevation. At each station a yellow plastic bowl (165 mm diameter × 40 mm depth) was placed on the forest floor and charged with propylene glycol. These yellow pan traps were left for seven days and serviced at the end of this period, with each station being retained as a separate sample. [See Chapter on Ichneumonid (Hymenoptera) diversity, by Simon van Noort in this volume for additional details.]

(6) Sweep netting (S). Fifty samples, each sample comprising 20 net sweeps (each sweep encompassing an arc of 180°) i.e., 1,000 sweeps, were taken at each elevation. The collection of these samples was spaced over a period of seven days at each elevation. Each sweep was conducted in previously unsampled vegetation. [See Chapter on Ichneumonid (Hymenoptera) diversity, by Simon van Noort in this volume for additional details.]

(7) General collecting (G). Ants were also surveyed through general collecting, defined as any collection method that was separate from the quantitative transect and Malaise trap methods described above. It included searching rotten logs and stumps, dead and live branches and twigs, low vegetation, termite mounds, and under stones.

Data analysis

Only records of ant workers were used in data analysis since the presence of queens or males in samples does not necessarily signify the establishment of a colony of that species within the transect habitat type. Voucher specimens for this study have been deposited at the California Academy of Sciences, San Francisco, California, U.S.A.

Overlap and complementarity (distinctness or dissimilarity, *sensu* Colwell and Coddington 1994) of the ant assemblages at different elevations were assessed using distinctness and beta-diversity indices. Complementarity of ant assemblages at different elevations was assessed using the proportion of all species in two sites that occurred at only one site. Complementarity was calculated using the Marczewski-Steinhaus (M-S) distance index: $C_{MS} = (a + b - 2j)/(a + b - j)$ where j = number of species found at both elevations, a = number of species at elevation A, and b = number of species at elevation B (Colwell and Coddington 1994). M-S was chosen because of its simple and statistically valid approach to comparing two biotas (Colwell and Coddington 1994).

Beta-diversity (species turnover between elevations) was calculated using the measure of beta-diversity developed by Harrison et al. (1992), because it distinguishes between species turnover and the loss of species along a gradient without adding new species. Beta = (S/a_{max}) 1, where S = the total number of species in the two elevations combined, and a_{max} = the maximum value of alpha-diversity (i.e., number of species) between the elevations compared. The number of species unique to an elevation and the number of species shared between elevations were also compared.

The redundancy of quantitative methods to capture the same portion of the fauna was evaluated using the redundancy index (R): $R = 1 - u/a$, where u = the number of species found only by method *min*, where *min* is the method that collected the fewest number of species, and a = the total number of species collected by the method that captured the fewest species (Fisher 2002). Higher values represent greater redundancy: a value of 1 represents complete redundancy, where all species collected by the method that captured the fewest species are also collected by the other method, and a value of 0 represents no overlap between species captured by each method.

RESULTS

Three hundred and ten species of ants in 56 genera, were collected on Monts Doudou (Table 1). Genera with 10 or more species were: *Tetramorium* (34 species), *Pyramica* (23), *Monomorium* (21), *Camponotus* (16), *Pheidole* (15), *Crematogaster* (13), *Oligomyrmex* (12), *Strumigenys* (12), *Technomyrmex* (12), *Cataulacus* (11), *Polyrhachis* (11) and *Pachycondyla* (10). Strictly arboreal species constituted approximately 27% of the total species richness (assessed from Table 1 on the basis of collecting method and previous knowledge of biology).

Elevation had no measurable effect on species richness, with the number of species at the two upper elevations being identical (206 species) and only four less than the number at the lowest elevation (210 species) (Table 2). The number of species unique to 640 m (34) was similar to 375 m (31) but less than 110 m (50).

TABLE 1. Species list of ants for collections on Monts Doudou based on two leaf litter sifting transects (L1, L2) beating (B), pitfall traps (P), sweeping (S), yellow pan traps (Y), Malaise traps (M), and general collecting (G). A total of 310 ant species were collected.

Species	110 m	375 m	640 m
AENICTINAE			
Aenictus sp. 03	Y	Y	–
Aenictus sp. 05	–	–	L1
CERAPACHYINAE			
Cerapachys sp. 01	G	–	–
Cerapachys sp. 02	L1, L2, Y	L1, L2, G, S	L1, L2, Y
Cerapachys sp. 03	L1, L2	L1, L2	L1, M
Cerapachys sp. 05	L1	L1	L2,
Cerapachys sp. 06	L2	L2	L2
Cerapachys sp. 10	L2	–	L2
Cerapachys sp. 11	–	L1	–
Cerapachys sp. 12	G		–
Cerapachys sp. 13	–	L2	L1, L2
Simopone conradti	–	M	–
Simopone sp. 03	–	L2, M	B
DOLICHODERINAE			
Axinidris sp. 01	G	–	B
Axinidris cf. *murielae*	B, S	–	B, S
Tapinoma sp. 02	B	L1, B, M, S	S, M
Tapinoma sp. 04	S	–	–
Technomyrmex sp. 01	B	–	B, M
Technomyrmex sp. 02	L1, S	L1, L2, B, S	L1, L2, B, M, S
Technomyrmex sp. 03	L1, L2, Y	L1, L2, G, Y	L1
Technomyrmex sp. 04	–	–	L2, B, S, Y
Technomyrmex sp. 06	–	–	B, S
Technomyrmex sp. 08	L2	L1, L2	–
Technomyrmex sp. 09	–	L1	–
Technomyrmex sp. 10	L1	L1, L2, B, S	–
Technomyrmex sp. 11	M	L1	B
Technomyrmex sp. 12	–	–	L1, B, G, S
Technomyrmex sp. 13	–	L2, S	S
Technomyrmex sp. 14	S	–	–
DORYLINAE			
Dorylus fulvus	–	L1	–
Dorylus sp. 01	P	P	G
Dorylus sp. 04	–	–	P
Dorylus sp. 06	L2	L1, G	G
Dorylus sp. 07	L1, L2	L1, Y	–

Species	110 m	375 m	640 m
FORMICINAE			
Acropyga sp. 02	L1	L2	L2
Acropyga sp. 07	–	–	L2
Anoplolepis sp. 01	L1	–	L2
Brachymyrmex sp. 01	S	–	–
Camponotus sp. 03	–	P	L2, P, G, M
Camponotus sp. 04	–	B	G, S
Camponotus sp. 05	–	B	S
Camponotus sp. 09	–	P	B
Camponotus sp. 13	–	–	G
Camponotus sp. 16	P, M, Y, S	B, P, Y, M, S	P, G, M
Camponotus sp. 18	–	B, G	G
Camponotus sp. 19	–	S	B
Camponotus sp. 20	B	–	B, M
Camponotus sp. 23	L2, B, G, M, S	S	–
Camponotus sp. 24	M, S	–	–
Camponotus sp. 25	S	–	–
Camponotus sp. 29	–	–	G
Camponotus sp. 30	–	–	L2
Camponotus sp. 37	–	–	G
Camponotus sp. 38	B	B, G	B
Lepisiota sp. 01	–	–	S
Lepisiota sp. 02	S	–	–
Lepisiota sp. 03	–	S	–
Lepisiota sp. 04	S	–	M
Lepisiota sp. 05	–	L2	B, S
Lepisiota sp. 06	–	–	G, S
Lepisiota sp. 07	–	–	S
Lepisiota sp. 09	–	L2, S	–
Ocecophylla longinoda	G	B, M, S	B, S
Paratrechina sp. 01	S	L1, L2, B, S	L1, L2, Y, S
Paratrechina sp. 02	–	–	S
Paratrechina sp. 03	G, S	L1, P, S	L1, L2
Paratrechina sp. 04	–	–	L2
Paratrechina sp. 06	S	L1	S
Paratrechina sp. 09	L2, S	L2, B, S	L1, L2, S
Paratrechina sp. 10	B, S	–	B, S
Paratrechina sp. 11	–	L1, Y	L1, B
Paratrechina sp. 13	S, M	–	–
Plagiolepis sp. 01	S	–	–
Plagiolepis sp. 02	SY	–	–
Plagiolepis sp. 03	S	–	–

274

Species	110 m	375 m	640 m
Plagiolepis sp. 09	B	–	–
Polyrhachis alexisi	S	–	–
Polyrhachis concava	S	B, S	–
Polyrhachis decemdentata	S	L2, P, S, M	–
Polyrhachis fissa	B	B, S, M	S
Polyrhachis laboriosa	S	–	–
Polyrhachis latispina	–	B	L2
Polyrhachis lestoni	–	B	–
Polyrhachis militaris	L2, B, P, G, Y, S	B, S	P, G, S
Polyrhachis monista	–	S	–
Polyrhachis revoili	B, S	B, S	B, S
Polyrhachis rutipalpis	G, S	L1, L2, S	G, S
Pseudolasius sp. 01	G	L1, L2	L1
Pseudolasius sp. 03	G	–	–
Pseudolasius sp. 05	L1	–	–
Santschiella kohli	–	S	–
MYRMICINAE			
Ankylomyrma corona-acantha	–	–	B
Atopomyrmex calpo-calycola	S, M	–	–
Atopomyrmex mocquerysi	–	–	G
Baracidris sitra	L1, L2	L2	–
Calyptomyrmex barak	L2, G	–	–
Calyptomyrmex brevis	–	L2	–
Calyptomyrmex kaurus	L1, L2	L1, L2	L1, L2
Cardiocondyla emeryi	S	–	–
Cataulacus sp. 01	B, G, S	B	B, S
Cataulacus sp. 02	–	B, S	–
Cataulacus sp. 03	B	–	–
Cataulacus sp. 04	–	–	B,
Cataulacus sp. 05	G, S	–	–
Cataulacus sp. 06	–	L2, B, G, S, M	B, S, Y
Cataulacus sp. 07	B, S	S, M	S
Cataulacus sp. 08	B, G	S	G, M, S
Cataulacus sp. 09	–	S, M	M, S
Cataulacus sp. 11	B	–	M
Cataulacus sp. 12	–	L1, B	–
Crematogaster sp. 01	L2, S	–	–
Crematogaster sp. 03	L1, L2, B, G, M, Y, S	L1, L2, B, P, G, M, S, Y	L1, L2, B, M, Y, S
Crematogaster sp. 04	S	–	–
Crematogaster sp. 05	S	S, M	–

275

Species	110 m	375 m	640 m
Crematogaster sp. 07	L2	–	–
Crematogaster sp. 08	S, Y	L2, B	–
Crematogaster sp. 10	–	–	M, S
Crematogaster sp. 11	L1, M, S	S	L1, L2, B, S
Crematogaster sp. 12	B, M, S, Y	M, S	L1, M, S
Crematogaster sp. 13	B, S	–	–
Crematogaster sp. 14	S	–	S
Crematogaster sp. 15	B	B, S, M	G
Crematogaster sp. 18	S	–	B
Cyphoidris exalta	–	–	P
Decamorium decem	L1, L2, G, Y	L1, L2, Y	
Dicroaspis laevidens	L1, L2, G	–	G
Melissotarsus emeryi	L2	–	–
Meranoplus nanus	S	–	B
Microdaceton tibialis	–	L1	L1, L2
Monomorium thrascoleptum	–	L1, L2	L1, L2
Monomorium cf. cryptobium	L1, L2	L1, L2	L1, L2
Monomorium cf. tanysum	L1, B, S	B	B
Monomorium cryptobium	L1, L2, G	L1, L2	L1, L2
Monomorium draxocum	–	L2, S	L1, L2, M, S
Monomorium egens	L1, B, S	S	L1, B, S
Monomorium exiguum	L2, B, S	B, G, S	B
Monomorium guineense	L2	–	–
Monomorium invidium	L1, L2	–	–
Monomorium nr. invidium	L1, L2	L1, L2	L1, L2
Monomorium spectrum	L1, L2, S	L1, L2, G, S	L1, L2, S
Monomorium strangulatum	L1, S	L2, B, S	
Monomorium sp. 01	B, S	B, S	B, S
Monomorium sp. 02	–	–	L1
Monomorium sp. 03	L1		L1, L2
Monomorium sp. 04	L1	M	B, S
Monomorium sp. 05	L2	–	B
Monomorium sp. 06	–	B	–
Monomorium sp. 07	–	B	–
Monomorium sp. 08	S	–	–
Monomorium sp. 09	–	–	L1, M
Myrmicaria exigua	L, S	M	M
Myrmicaria sp. 01	G, S, M	L1, L2, G, S, Y	–
Oligomyrmex nr. viliersi	L1	–	L2
Oligomyrmex sp. 01	L1	L1, L2, G	L1, L2
Oligomyrmex sp. 02	L1, L2	L1	L1, L2, S
Oligomyrmex sp. 03	L1, L2	L1, L2	L1, L2, G

Species	110 m	375 m	640 m
Oligomyrmex sp. 04	–	L1, L2, G	L1, L2, G
Oligomyrmex sp. 05	L1, L2	L1, L2	L1, L2
Oligomyrmex sp. 06	L1	L1, L2	L1, L2
Oligomyrmex sp. 07	L1, L2	L1	L1, L2
Oligomyrmex sp. 08	L2, S	L1	–
Oligomyrmex sp. 09	L1, L2	–	–
Oligomyrmex sp. 10	L1, L2	L1, L2	L1
Oligomyrmex sp. 11	–	–	L2
Paedalgus cf. *rarus*	–	–	L2
Pheidole megacephala	L1, B, G, S, M	L2, B, M, S, Y	L1, L2, B, S, Y, M
Pheidole nr. *pulchella*	G, Y	L2, S, Y	L1, L2
Pheidole speculifera	L1, L2, G, Y	L1, L2, G, Y, M	L2, G
Pheidole sp. 02	L1, L2, B, G, S, M, Y	L1, L2, B, G, S, Y	L1, B, M, S
Pheidole sp. 03	–	L2, G	–
Pheidole sp. 04	–	L1, G, S, Y	L1, L2
Pheidole sp. 05	L1	L1, L2	L1, L2, S
Pheidole sp. 06	L1, Y	L1, L2, G, S	L1, L2, S
Pheidole sp. 07	L1, L2	L1, L2	L1, L2
Pheidole sp. 08	Y	G	–
Pheidole sp. 09	L1, L2	L1, L2, Y	L1, L2
Pheidole sp. 10	L1, L2	L2	–
Pheidole sp. 11	–	L1, L2, G	L1, L2, G
Pheidole sp. 12	L1, L2	L1, L2	L1, L2
Pheidole sp. 13	L1, L2, G	L1, L2, G, Y	L1, L2
Pristomyrmex africanus	L1, L2, G	L1, L2, G	L1, L2, M
Pristomyrmex orbiceps	L1, L2, S	L1, L2, G	L1, L2
Pyramica behasyla	L2	L1, L2	L2
Pyramica belial	L2	–	–
Pyramica concolor	L1	L1, L2	L1, L2
Pyramica convinasis	–	–	L2
Pyramica depilosa	L2, S	L1, L2	L1
Pyramica dotaja	L1, L2	L1, L2	L1, L2
Pyramica enkara	L1, L2	L1, L2	L1, L2
Pyramica hensekta	–	L1	L2
Pyramica kerasma	L2	–	L1, L2
Pyramica lasia	–	–	L2
Pyramica laticeps	L1, L2	–	–
Pyramica ludovici	L1, L2	L1, L2, G	L1, L2
Pyramica lujae	–	L1	L1, L2, G
Pyramica ninda	L1	L1, L2	L1, L2
Pyramica placora	L1, L2	L1	L2
Pyramica ravidura	L1	L1, L2	L2

Species	110 m	375 m	640 m
Pyramica roomi	–	L2	–
Pyramica serrula	L1, L2	L1, L2	L1, L2, S
Pyramica sharra	L1, L2	–	L2
Pyramica synkara	L1, L2	L1	L2
Pyramica tacta	–	L1	L1, L2
Pyramica tethapa	–	L2	–
Pyramica tetragnatha	L1, L2	L1, L2, S	L1, L2, S
Strumigenys bernardi	L1, L2	L1, L2	L1, L2
Strumigenys cacaoensis	–	–	L2, S
Strumigenys dextra	L1, L2	L1, L2	L1, L2
Strumigenys korahyla	–	–	L2
Strumigenys petiolata	L1, L2, Y	L1, L2	L1, L2
Strumigenys rogeri	L1	L1	–
Strumigenys spathoda	–	L2	–
Strumigenys tetraphanes	L2	L1, L2	L1, L2
Strumigenys totyla	–	–	L2
Strumigenys ultromalyx	–	L2	L1
Strumigenys sp. 01	–	L2	–
Strumigenys sp. 02	–	–	L1, L2
Tetramorium sp. 01	–	L1, L2	–
Tetramorium sp. 02	–	L2	S
Tetramorium sp. 03	L1, L2, S	L2	L1, L2
Tetramorium sp. 04	L1	L2, S, Y	L1, L2
Tetramorium sp. 05	L1, L2	L1, L2	L1, L2
Tetramorium sp. 07	–	L2, S	–
Tetramorium sp. 08	–	L1	–
Tetramorium sp. 09	L1, S	L1, L2, B, G, S	L1, L2, B, G, S, Y
Tetramorium sp. 10	L1	L2, S	L1, L2, Y
Tetramorium sp. 11	L1, L2, S	L1, G, S	L2
Tetramorium sp. 12	L1, L2	L1, L2, G	L1, L2
Tetramorium sp. 13	L1, L2	L2	–
Tetramorium sp. 14	L1, L2	L1, L2, Y	L1, L2
Tetramorium sp. 15	–	L1	L1
Tetramorium sp. 16	L1, L2, B	L1, B, G	B
Tetramorium sp. 17	L1, L2	L1	L1, Y
Tetramorium sp. 18	L1	–	–
Tetramorium sp. 19	L1, L2	L1, B	L1, L2, G
Tetramorium sp. 21	L1, L2, Y, S	L1, L2, B, G, Y	L1, L2
Tetramorium sp. 22	B	B	B
Tetramorium sp. 23	–	B	–
Tetramorium sp. 24	B, S	B, S	S
Tetramorium sp. 25	–	–	G

Species	110 m	375 m	640 m
Tetramorium sp. 26	S	L2, G, S	L1, L2, G, S
Tetramorium sp. 27	L1, L2, S	L1, L2, B, S	S
Tetramorium sp. 28	L1, B, S	B, M, S	B, G, S
Tetramorium sp. 30	–	L1, L2	L1, L2, G
Tetramorium sp. 31	–	G	–
Tetramorium sp. 32	–	–	L2
Tetramorium sp. 33	L1, L2, S	L1	L2, G
Tetramorium sp. 34	L1, L2, G	L1, G, Y	–
Tetramorium sp. 35	–	L1	L2
Tetramorium sp. 36	S	L1, L2, S, Y	S
Tetramorium sp. 37	–	S	–
PONERINAE			
Amblyopone sp. 01	L1	G	–
Anochetus africanus	L1, L2	L1, L2, P, G	L1, L2
Anochetus nr. *africanus*	L2, G	L1, G	L1,
Anochetus katonae	L1, L2, G	L1, L2	L1, L2
Anochetus sp. 01	–	L1, L2	L1, L2
Anochetus sp. 02	–	L1, L2, G	–
Anochetus sp. 03	L1, L2, G	L2	–
Anochetus sp. 04	L1	L1, L2	–
Anochetus sp. 05	L1, G, S	L1, L2, B	L1, L2
Centromyrmex bequaerti	–	L1, G	–
Centromyrmex sellaris	L2, G	–	–
Discothyrea sp. 01	L2	L1, L2	L1, L2
Discothyrea sp. 03	L1, L2	L1, L2	L1
Hypoponera sp. 01	L1	L1, L2, G	L1, L2
Hypoponera sp. 02	L2	–	–
Hypoponera sp. 03	L1, L2, G	L1, L2	L1, L2, G
Hypoponera sp. 04	–	L1, L2, G	L1, L2, G
Hypoponera sp. 06	–	G	–
Leptogenys amon	–	L1	–
Leptogenys bubastis	L1	–	–
Leptogenys camerunensis	P	–	–
Leptogenys conradti	L1, G	–	–
Leptogenys occidentalis	L1, L2	L1, L2, G	L1, L2
Leptogenys sp. 05	–	L1	–
Leptogenys sp. 07	L1, L2	–	–
Loboponera basalis	L2	–	–
Loboponera vigilans	G	–	–
Odontomachus assiniensis	P	L1, L2, P, G	L1
Odontomachus troglodytes	L2, G, Y	–	P
Pachycondyla ambigua	L1, L2	L1	L1, L2

279

Species	110 m	375 m	640 m
Pachycondyla cattvaria	L1, L2	L1, L2	L1, L2
Pachycondyla cf. sharpi	L1, L2, G	L1, L2	L1, L2
Pachycondyla pachyderma	P, Y	L1, L2, G	L1, L2, P, G, Y
Pachycondyla sjostedti	L1, G	G	G
Pachycondyla tarsata	L1, L2, L, P, Y	L2, P, Y	L1, L2, P, Y
Pachycondyla sp. 01	L1, L2, P	L1, P, G	L1, P, G, S
Pachycondyla sp. 02	–	L1	L1, L2
Pachycondyla sp. 03	–	L1, L2	L1, L2
Pachycondyla sp. 04	L1, L2	L1, L2	L1, L2
Phrynoponera bequaerti	L1, L2, G	L1, L2	L1, L2, P,
Phrynoponera gabonensis	L1, L2, P	L1, P	L1, P, Y, Y
Phrynoponera heterodus	P	L1, L2, P	L1, L2, P
Phrynoponera sveni	G	–	–
Platythyrea conradti	G	–	–
Platythyrea gracillima	–	G	–
Platythyrea modesta	M	–	M, S
Plectroctena minor	G	–	–
Plectroctena ugandensis	G	–	–
Prionopelta sp. 01	L2	L1, L2	L1, L2
Prionopelta sp. 02	–	L2	L1, L2
Prionopelta sp. 03	–	–	L2
Probolomyrmex sp. 01	L1, L2	L1, L2	L2
Psalidomyrmex procerus	–	G	L1
PSEUDOMYRMICINAE			
Tetraponera aethiops	–	P, G	–
Tetraponera anthracina	G, S	–	–
Tetraponera cf. liengmei	–	–	S
Tetraponera mocquerysi	G, S	–	–
Tetraponera ophthalmica	M	–	–
Tetraponera sp. 03	S	–	–

TABLE 2. Complementarity and species turnover between the three elevational zones based on all methods sampled in Monts Doudou. The Marczewski-Steinhaus (M-S) complementarity measure is above the diagonal and Harrison index of Beta diversity is below. Higher values represent greater distinctness (M-S) or turnover (Beta). The number of species shared between elevations is presented in parentheses.

Elevation	110 m	375 m	640 m
110 m (210 spp.)	–	0.489 (141)	0.505 (138)
375 m (206 spp.)	0.308	–	0.415 (152)
640 m (206 spp.)	0.322	0.262	–

Measures of species turnover (beta) and distinctness (M-S) between elevations were very similar overall (Table 2). The 110-meter and 640-meter sites had the greatest species turnover (beta) and distinctness (M-S), while the 375-meter and 640-meter sites had the lowest (Table 2).

The two litter transects at 110 m, which were located 16.4 km apart, did not have the greatest distinctness and species turnover (M-S) compared to transects located closer than 1 km at 375 m and 640 m (Table 3). Transects at 640 m had the lowest distinctness and turnover.

Leaf litter samples captured the greatest number of species at each elevation followed by sweeping (Table 4). Yellow pan, pitfall and Malaise traps collected the fewest species.

Based on the collecting protocols employed in this study, the optimal sequence of collecting methods to maximize species capture is listed in Table 5. Litter + Sweeping + 2nd transect of Litter sampling was the most productive sequence of methods at all elevations. The next most productive was beating and general collecting but their rank changed with elevation.

TABLE 3. Complementarity and species turnover between the two 50-sample leaf litter transects at each elevation. Higher values represent greater distinctness (M-S) or turnover (Beta).

	110 m	375 m	640 m
Number species shared	70	80	84
M-S	0.466	0.491	0.387
Beta	0.260	0.283	0.181
Total number species	131	154	137

TABLE 4. Number of species collected in Monts Doudou by each collecting method at each elevation. Numbers of species unique to each elevation are in parentheses.

	Elevation		
Method	110 m	375 m	640 m
Litter sifting: transect 1	104	120	105
Litter sifting: transect 2	97	114	116
Sweeping	71	56	56
General collecting	44	47	36
Beating	32	42	38
Matlaise traps	14	19	21
Yellow pan traps	20	21	12
Pitfall traps	10	14	12
All methods	210 (50)	206 (31)	206 (34)

TABLE 5. Optimal order of methods to capture the greatest number of species for each elevation, based on the 8 methods used in this survey. The cumulative number of species captured is in parentheses. L1, L2 = leaf litter sifting transects; B = beating; S = sweeping G = general collecting (G). Yellow pan traps, Malaise, and pitfall added very few new species.

Elevation	Method
110 m	L1 (104)+ S (157) +L2 (177)+ G (190) + B (200)
375 m	L1 (120)+ S (158)+ L2 (177) + B (191) + G (199)
640 m	L1 (105)+ S (141) + L2 (177) + B (188) + G (200)

The analysis of redundancy clearly shows a division in methods to either capture species living or foraging on the ground or soil versus species foraging and nesting above ground (Table 6). Leaf litter, pitfall and yellow pan traps formed one group with high redundancy that captured the ground assemblage, while sweeping, beating and Malaise traps had high redundancy and captured the arboreal assemblage. General collecting was more redundant with the methods that captured the ground community than with methods that trapped the arboreal community. Of note was that even though the two leaf-litter transects conducted at each elevational zone were highly redundant (R = 0.695–0.722), the second transect still captured a greater number of new species than all less redundant methods except sweeping (Table 5, 6).

DISCUSSION

Species richness

The 310 species of ants recorded in Monts Doudou represent the greatest ant species richness yet recorded for a single region on the continent. In Tanzania, Robertson (1999) recorded 232 species, and in Ghana Belshaw and Bolton (1994) recorded 176 species, whilst Room recorded 128 species (Room 1971). The species count from Monts Doudou is also greater than any locations surveyed in Madagascar (Fisher 1996, 1998, 1999a, 2002; Fisher and Robertson 2002). The highest recorded species richness in Madagascar was 215 species at the Anjanaharibe-Sud Reserve in northeastern Madagascar (Fisher 1998). A comparison between 50-sample, leaf litter transects on Monts Doudou and low elevation sites in Madagascar (25–1240 m) also shows greater richness in Gabon than in Madagascar. In this study, the average number of species captured in a 50-sample, leaf litter transect in Gabon was 109.3 species (SD ± 8.7, N = 6) while in Madagascar an average of 80.3 species were captured in a similar area. (SD ± 16.2, N = 12).

The recorded species richness on Monts Doudou, however, is inferior to inventories conducted in the wet tropics in Central America, South America, and in southeast Asia. Longino and colleagues (2002) reported 437 species from La Selva Biological Station, Costa Rica. Brühl and colleagues (1998) found 524 species in Kinabaloo National Park, Borneo. Verhaagh (1990, 1991) reported 520 species in Panguana Reserve, Peru. All of these inventories employed a complement of collecting methods and strongly suggest that the wet forest in Africa has lower ant diversity than similar habitat in Southeast Asia and the New World. Future work comparing studies that include measures of inventory completeness will be necessary to confirm this preliminary result.

TABLE 6. Redundancy of quantitative methods used to capture the same portion of the fauna. See text for explanation of redundancy index (R). Higher values represent greater redundancy. Leaf litter sifting transects (L1, L2), beating (B), pitfall traps (P), general collecting (G), sweeping (S), yellow pan traps (Y), and Malaise traps (M).

(a) Elevation 110 m (above diagonal) and 375 m (below)

	L1	L2	B	P	G	S	Y	M
L1	–	0.722	0.250	0.300	0.409	0.254	0.500	0.286
L2	0.702	–	0.219	0.400	0.455	0.183	0.550	0.214
B	0.310	0.333	–	0.200	0.219	0.594	0.250	0.357
P	0.500	0.429	0.143	–	0.100	0.200	0.400	0.100
G	0.702	0.596	0.214	0.357	–	0.295	0.350	0.357
S	0.321	0.214	0.571	0.286	0.255	–	0.400	0.786
Y	0.714	0.714	0.238	0.214	0.429	0.429	–	0.286
M	0.158	0.316	0.474	0.214	0.158	0.737	0.211	–

(b) Elevation 640 m

	L1	L2	B	P	G	S	Y	M
L1	–	0.695	0.237	0.500	0.382	0.357	0.833	0.429
L2		–	0.158	0.417	0.412	0.179	0.750	0.286
B			–	0.000	0.088	0.526	0.417	0.286
P				–	0.417	0.167	0.250	0.167
G					–	0.294	0.167	0.143
S						–	0.500	0.524
Y							–	0.167

Productive methods

The survey on Monts Doudou is the most thorough inventory conducted in Africa to date. The high species richness of this study is due in part to the variety of methods used to capture ants. Every method employed captured additional species. A critical issue associated with invertebrate inventories is determining which method and sampling design is the most efficient. As reported in other studies (Fisher 1999b; Fisher and Robertson 2002), litter sifting captured the most species. Based upon the number of species captured, Malaise, yellow pan, and pitfall were the least productive methods. Sweeping is rarely used in ant inventories but these results suggest that it should be included to complement litter sampling. Sweeping also collected rare ants such as *Santschiella kohli* (Fig. 1), which had yet to be recorded in Gabon.

Elevational variation

Elevation had no measurable effect on species richness and composition. In studies in Madagascar (Fisher 1996, 1998, 1999a, 1999b, 2002) along an elevational gradient from approximately 25 m to 2,000 m, species richness peaked at mid-elevation (800 m) and declined rapidly after 1,200 m. In addition, these studies in Madagascar showed distinct montane and lowland ant assemblages. The results from this study suggest that Monts Doudou does not have a unique mountain ant fauna at the 640-meter site. Mountains with higher elevation such as Monts Cristal, which reaches just over 1,000 m, should be investigated for possible montane elements in Gabon.

FIGURE 1. *Santschiella kohli*, a rare species, collected by sweeping at 375 m.

There is limited information on the distribution pattern of ants in the Congo Basin. Thanks to the recent work of Bolton (2000) there is one diverse group, the tribe Dacetonini, which has been sufficiently documented to permit an evaluation of the uniqueness of the ant fauna on Monts Doudou. The Dacetonini (*Microdaceton*, *Pyramica*, and *Strumigenys*) on Monts Doudou comprised 36 species, all but two of which have previously been recorded from Gabon or in neighboring countries and have broad distribution ranges across the western Congo Basin.

The 110-meter zone was the only site surveyed that showed signs of habitat disturbance. This site was selectively logged for a few species. This activity seemed to have little effect on the ant fauna in the areas surveyed. Along the roads that were established to extract logs, however, the invasive exotic ant *Wasmannia auropunctata* was seen. It is possible that with time, this invasive ant will penetrate the forest away from the road edges. *Wasmannia auropunctata* was first recorded in Gabon in 1914 in Libreville, Gabon (Santschi 1914) and has recently been recorded from réserve de la Lopé (Wetterer et al. 1999).

Inventories are a crucial step in the conservation process and provide the baseline documentation of species and their natural occurrence. Patterns of species richness, turnover, and endemism are three criteria for conservation assessment that require knowledge of species' spatial distributions. There are arguments to base conservation decisions on alternative criteria (such as threat or uniqueness of habitat or ecosystem), but there is still a critical need to define areas of high endemism and species richness if the maximum diversity is to be preserved. The best sustainable management decisions are based on thorough knowledge of the inhabitants to be conserved. Accurate environmental information is important for land management in Gabon and this requires taxonomic knowledge. We must continue to develop the taxonomic capacity of African scientists to ensure that baseline biodiversity data is available for sound conservation and sustainable use planning.

Leptogenys; Brian Heterick identified *Pheidole* and *Monomorium*; Helian Ratsirarson sorted *Tetramorium*; Rudy Kohout identified *Polyrhachis*; and Philip Ward identified *Tetraponera*.

LITERATURE CITED

AGOSTI, D., J. D. MAJER, L. E. ALONSO, AND T. R. SCHULTZ, eds. 2000. Ants. Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press, Washington. 280 pp.

BELSHAW, R. AND B. BOLTON. 1994. A survey of the leaf litter ant fauna in Ghana, West Africa (Hymenoptera: Formicidae). Journal of Hymenoptera Research 3:5–16.

BOLTON, B. 2000. The ant tribe Dacetini. Memoirs of the American Entomological Institute 65:1–1028.

BRÜHL, C. A., G. GUNSALAM, AND K. E. LINSENMAIR. 1998. Stratification of ants (Hymenoptera: Formicidae) in a primary rain forest in Sabah, Borneo. Journal of Tropical Ecology 14:285–297.

COLWELL, R. K. AND J. A. CODDINGTON. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London. Series B 345:101–118.

FISHER, B. L. 1996. Ant diversity patterns along an elevational gradient in the Réserve Naturelle Intégrale d'Andringitra, Madagascar. Fieldiana: Zoology (n. s.) 85:93–108.

———. 1998. Ant diversity patterns along an elevational gradient in the Réserve Spéciale d'Anjanaharibe-Sud and on the western Masoala Peninsula, Madagascar. Fieldiana: Zoology (n. s.) 90:39–67.

———. 1999a. Ant diversity patterns along an elevational gradient in the Réserve Naturelle Intégrale d'Andohahela, Madagascar. Fieldiana: Zoology (n. s.) 94:129–147.

———. 1999b. Improving inventory efficiency: a case study of leaf litter ant diversity in Madagascar. Ecological Applications 9:714–731.

———. 2002. Ant diversity patterns along an elevational gradient in the Réserve Spéciale de Manongarivo, Madagascar. Boissiera 59:311–328.

FISHER, B. L. AND H. ROBERTSON. 2002. Comparison and origin of forest and grassland ant assemblages in the high plateau of Madagascar. Biotropica 34:155–167.

FRANKS, N. R. AND W. H. BOSSERT. 1983. The influence of swarm raiding army ants on the patchiness and diversity of a tropical leaf litter ant community. Pp. 151–163 *in* Tropical rain forest: ecology and management, S. L. Sutton, T. C. Whitmore, and A. C. Chadwick, eds. Blackwell, Oxford.

GOTWALD, W. H., JR. 1995. Army ants: the biology of social predation. Cornell University Press, Ithaca, New York. 302 pp.

HARRISON, S., S. J. ROSS, AND J. H. LAWTON. 1992. Beta diversity on geographic gradients in Britain. Journal of Animal Ecology 61:151–158.

HÖLLDOBLER, B. AND E. O. WILSON. 1990. The ants. Harvard University Press, Cambridge, Mass. 732 pp.

LONGINO, J. T., J. CODDINGTON, AND R. K. COLWELL. 2002. The ant fauna of a tropical rain forest: estimating species richness three different ways. Ecology 83:689–702.

MAJER, J. D. AND A. E. DE KOCK. 1992. Ant recolonization of sand mines near Richards Bay, South Africa: an evaluation of progress with rehabilitation. South African Journal of Science 88:31-37.

ROBERTSON, H. G. 1999. Ants (Hymenoptera: Formicidae) of Mkomazi. Pp. 321–336 *in* Mkomazi: the ecology, biodiversity and conservation of a Tanzanian savanna, M. Coe, N. McWilliam, G. Stone, and M. J. Packer, eds. Royal Geographical Society, London.

———. 2000a. Afrotropical ants (Hymenoptera: Formicidae): taxonomic progress and estimation of species richness. Journal of Hymenoptera Research 9:71–84.

———. 2000b. Formicidae (Hymenoptera: Vespoidea). Pp. 371–382 *in* Dâures—Biodiversity of the Brandberg Massif, Namibia, A. H. Kirk-Spriggs and E. Marais, eds. Cimbebasia Memoir 9.

ROOM, P. M. 1971. The relative distributions of ant species in Ghana's cocoa farms. Journal of Animal Ecology 40:735–751.

SANTSCHI, F. 1914. Formicides de l'Afrique occidentale et australe du voyage de M. le Professeur F. Silvestri. Bollettino del Laboratorio di Zoologia generale e agraria (Portici, Italia) 8:309–385.

VERHAAGH, M. 1990. The Formicidae of the rain forest in Panguana, Peru: the most diverse local ant fauna ever recorded. Pp. 217-218 *in* Social insects and the environment, G. K. Veeresh, B. Mallick, and C. A. Viraktamath, eds. Oxford and IBH Publishing, New Delhi.

————. 1991. Clearing a tropical rain forest—effects on the ant fauna. Pp. 59–68 *in* Proceedings of the International and Interdisciplinary Symposium on Tropical Ecosystems, W. Erdelen, N. Ishwaran, and P. Müller, eds. Magraf Scientific, Weikersheim, Germany.

WETTERER, J. K., P. D. WALSH, AND L. J. T. WHITE. 1999. *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae), a highly destructive tramp ant, in wildlife refuges of Gabon, West Africa. African Entomology 7:292-294.

Gazetteer

Note: Localities studied only by particular authors have the author name in parentheses.

Locality	Longitude E	Latitude S	Elevation (m)
Camp 1	2°17.00′	10°29.83′	110
Camp 2	2°13.35′	10°24.35′	350–425
Camp 3	2°13.63′	10°23.67′	585–660
Site 1 (Burger)	2°20.16′	10°35.47′	100
Site 2 (Burger, Fisher)	2°25.36′	10°32.72′	110
Site 3 (Burger)	2°19.24′	10°32.16′	110
Site 4 (Burger)	2°17′	10°29′	110
Site 5 (Burger)	2°17′	10°29′	110
Site 7 (Burger)	2°15′	10°29′	110
Mont Pongou (Sosef)	2°14′	10°23′	600–700
Mont Mougoubi (Sosef)	2°24′	10°26′	600–700
Plot 1 (Sosef)	2°17′	10°30′	100
Plot 2 (Sosef)	2°17′	10°30′	100
Plot 3 (Sosef)	2°14′	10°27′	150
Plot 4 (Sosef)	2°17.6′	10°30.3′	150
Plot 5 (Sosef)	2°13′	10°24′	380
Plot 6 (Sosef)	2°13′	10°24′	460
Plot 7 (Sosef)	2°14′	10°24′	650
Plot 8 (Sosef)	2°13′	10°24′	350
Plot 9 (Sosef)	2°27.6′	10°32′	195
Plot 10 (Sosef)	2°27.4′	10°32′	535
Plot 11 (Sosef)	2°27.4′	10°32.1′	430
Plot 12 (Sosef)	2°28′	10°32′	145
Plot 13 (Sosef)	2°27.6′	10°32.5′	265
Plot 14 (Sosef)	2°28′	10°32.5′	150
Plot 15 (Sosef)	2°23.1′	10°30.7′	545
Plot 16 (Sosef)	2°24.4′	10°27.1′	655
Plot 17 (Sosef)	2°22.5′	10°28.8′	225
Plot 18 (Sosef)	2°23′	10°29.5′	230

INDEX TO TAXA

Please scan
under barcode:

39088013625978

no. 28 (2004)